



Environmental damage

An environmental footprint for illegal waste transports

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Environmental damage - An environmental footprint for illegal waste transports

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EXECUTIVE SUMMARY

The WasteForce project aims to boost the operational activities and capacities of authorities involved in the fight against illegal trade and management of waste. Illegal trade, disposition and handling of waste can cause different types of impacts like health risks, environmental damage, contamination of agricultural goods and economic damage.

In deliverable 2.3 *Environmental Damage* existing technical methods to estimate risks, impact and damage of illegal waste trafficking are mapped on headlines. This overview starts with the information collected during road inspections. The waste codes on shipment documents, the (hazardous) properties of the waste and information with respect to the recovery and disposal operations are the fundamentals for subsequent risk assessments and Life Cycle Impact Assessments (LCIA).

The designed framework is used to generate information on health risks and environmental damage caused by individual waste transports. To facilitate the interpretation the impact is monetized. The impact of illegal waste transports on the different LCIA impact categories are shown in the figure below. The impact for the individual transports varied between €4000,- and €1.2 million with an average of €320.000,-. Lack of information and data make that this outcome should be considered as incomplete and probably largely underestimates the real impact of illegal waste trafficking. The evaluated cases also show that whereas the focus of the legislative framework seems to be on hazardous waste, the impact of illegal transports of non-hazardous waste is significant as well. Finally, it is known that waste streams, production processes, illegal activities and the technical possibilities to evaluate the impact develop fast. As a consequence, methodologies will need regular updating.

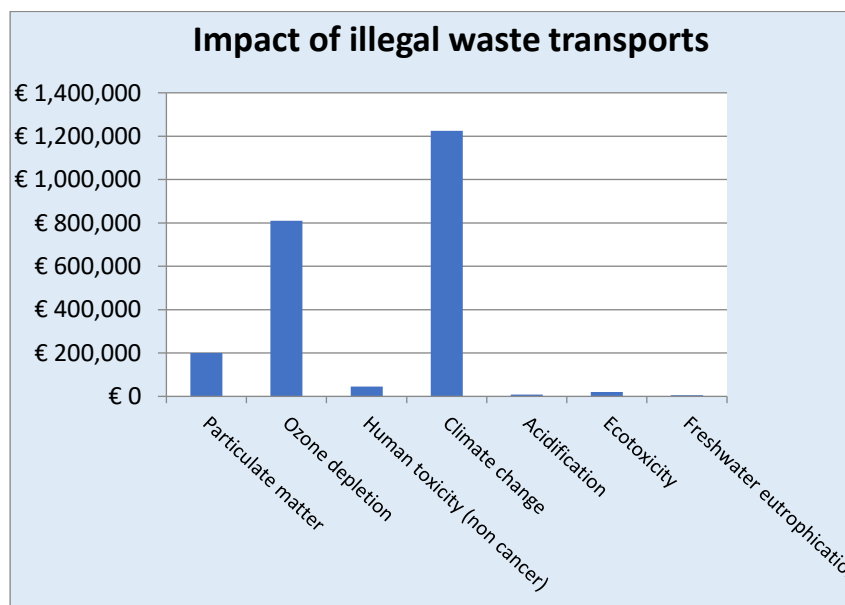


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AIM AND OBJECTIVES OF THE DELIVERABLE

The aim of WP2.3 *Environmental Damage* is to provide an overview of technical possibilities and a framework that can be used to estimate the impact on environment and human health of illegal transnational waste transports. The designed methodology is meant to assist law enforcement officers and public prosecutors.

Sharing results of past experiences creates insight in the type and number of victims, ecological damage and economic losses.

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LIST OF ABBREVIATIONS AND DEFINITIONS

CTUe	Comparative Toxic Unit for ecosystems (CTUe). CTUe expresses the affected fraction of species (PAF) over time and per unit mass of a chemical emitted
CTUh	Comparative Toxic Unit for human (CTUh). CTUh expresses the estimated increase in morbidity in the total human population per unit mass of a chemical emitted (disease cases per kilogram chemical emitted)
DALY	Disability Adjusted Life Years. One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability
Damage	Environmental damage or degradation is the deterioration of the environment through depletion of resources such as air, water and soil; the destruction of ecosystems and the extinction of wildlife. It is defined as any change or disturbance to the environment perceived to be deleterious or undesirable. Environmental damage is defined differently in different legal systems. The EU Environmental Liability Directive (ELD, 2004/35/EC), transposed effectively by all EU Member States as of July 2010, defines environmental damage as damage (harm) to protected species and natural habitats, water (within the scope of the EU Water Framework Directive) and land, if its contamination threatens human health
Endpoint area of protection	The environmental categories through which a substance emissions and releases to the environment are modelled up to the damage effects on the environmental aspects
ELV	End of Life Vehicle; According to definitions laid out in the Waste Framework Directive, it is primarily the customer's will which designates a given vehicle an end-of-life vehicle. However, in certain cases a vehicle is considered end-of-life simply due to the condition it is in. According to the Waste Shipment Regulation, such vehicle may not be exported outside of the European Union
Heterogeneity	The degree to which one constituent is non-uniformly distributed across the sample population
Homogeneity	The degree to which one constituent is uniformly distributed across the sample population
HP	Hazardous Property according to the Waste Framework Directive
Impact	An environmental impact is the result of environmental impacts on human health and welfare. The term is also used synonymously with environmental effect.
LCA	Life Cycle Analysis is a method used to evaluate the environmental impact of a product through its life cycle encompassing extraction and processing of the raw materials, manufacturing, distribution, use, recycling, and final disposal
LCIA	Life Cycle Impact Assessment is a method used to clarify the intensity of the LCA results with respect to their environmental effects, such as climate change, human health, and biodiversity. The LCIA is also used to conduct a comprehensive evaluation by integrating the environmental effects

Midpoint impact category	The environmental categories through which a substance emissions and releases to the environment are modelled up to the changes in the natural environmental aspects
Multigas Detector	A detector by which simultaneously different volatile substances can be measured, like oxygen, carbon monoxide, explosive gases (as measured by the lower explosive limit (LEL)) and hydrogen sulphide. A multigas detector can also have a PID sensor.
PID	<p>A photoionization detector or PID is an efficient and inexpensive gas detector by which volatile organic compounds and other gases can be measured. The PID is a useful tool for various types of emergencies such as hazardous materials incidents, oil or gasoline spills, technical rescue, leaking cylinders or gas valves, nuisance complaints for an odour of gas if VOC (volatile organic substances are involved). The benefits of the PID are its low cost, ease of operation, and near-instantaneous results and capability to measure low levels of VOCs.</p> <p>A limitation of the PID is that it does not identify chemical compounds by name. Unless it is combined with other detection technology in the same device, the PID only displays the aggregate concentration of VOCs present</p>
Risk assessment	In this study a risk assessment refers to the evaluation of the risks of sources of a stressors (or combination of stressors) on a given receptor (e.g. humans, ecosystems)
Waste	This document uses the qualification “waste” for all materials used as examples to illustrate the technical possibilities, knowing the qualification “waste” depends on the legal context and is not automatically applicable to all studied material
WEEE	Waste Electrical and Electronic Equipment

1. INTRODUCTION

The WasteForce project aims to boost the operational activities and capacities of authorities involved in the fight against illegal trade and management of waste. In WP 2.3. Environmental Damage the technical options to determine the different type of risks and damage caused by illegal transnational waste transports are mapped. In order to assist compliance officers and public prosecutors to determine the potential impact on human health and the environment of individual illegal waste transports a unified methodology will be developed. The information generated by applying the methodology in individual cases will be used to create more overall insight in the impact of illegal waste trafficking.

Under the Waste Shipment Regulation (Regulation 1013/2006/EC) which implements the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal* certain waste shipments are prohibited, including shipments of hazardous waste from the EU to non-OECD countries. For other shipments, the *Waste Shipments Regulation* prescribes either a notification procedure (the “Prior Informed Consent (PIC) procedure”) or information requirements.

UNEP and Interpol have estimated that environmental crime is the fourth most lucrative illegal business in the world, worth up to \$258 billion annually (EEB 2020). Illegal waste shipments have been identified as a serious problem existing at a significant scale. Inspections in recent years at sea-ports, on roads and in companies, have revealed that around 25% of shipments containing waste in the EU do not comply with the *Waste Shipment Regulation*. Although numerous reports by non-governmental organizations, media and studies have shown that large amounts of waste originating in the EU are illegally exported to countries in Africa and Asia overviews of the impact are incomplete (WHO 2015). The EFFACE¹ project generated information with respect to impact from illegal exports of e-waste from the EU to China (Geeraert, Mutafoglu and Illes 2015). Health impacts like a decreased lung function, physical growth of children, reduced reproductive health, increased DNA damage

and an average reduction of intelligence in children are to be expected due to activities with e-waste in China. Furthermore, it was estimated that the economic loss for the EU of illegal WEEE shipments to China is roughly €348 million for 2012 only.

These figures indicate that illegal waste shipments not only have negative impacts on environment and public health, but also disrupt recycling efforts. Sustainability and the creation of a circular economy is of growing prominence within the EU. The EC has adopted an EU action plan for the circular economy “Closing the loop”, which includes legislative proposals to amend current EU waste legislation, including the Waste Framework Directive, the Landfill Directive and the Directives on packaging and packaging waste and electrical and electronic waste (EC 2015). This is in line with the European Union waste hierarchy, which gives priority to reduced production and re-use or recycling of waste over incineration and landfilling. The concept is that waste can make a big contribution to economic growth and job creation. Studies show that full implementation of EU waste legislation would save €72 billion a year, increase the annual turnover of the EU waste management and recycling sector by €42 billion and create over 400.000 jobs by 2020 (BIO Intelligence Service 2011a) (EC 2012) (EC 2013).

¹ EFFACE-short for *European Union Action to Fight for Environmental Crime* was an EU funded research project. It assessed the impacts

of environmental crime as well as effective and feasible policy options for combating it. It ended in March 2016.

2. RESEARCH METHODOLOGY

Starting point of WP2.3 Environmental Damage is that estimates of potential and actual negative effects (damage or impact)² on the environment and human health caused by illegal waste transports must be based on information collected during interventions of waste transports by law enforcement officers. WP 2.3 starts with an inventory of technical possibilities to collect information with respect to the identity of the waste, its hazardous characteristics, ways to determine exposure and finally procedures to estimate risks and impacts (see figure 1). Information is mostly based on literature and open source databases. In chapter 4 illegal waste transports will be analysed and an Environmental Footprint of the potential damage will be generated based on the methodology described in chapter 3. Cases are provided by WasteForce partners.

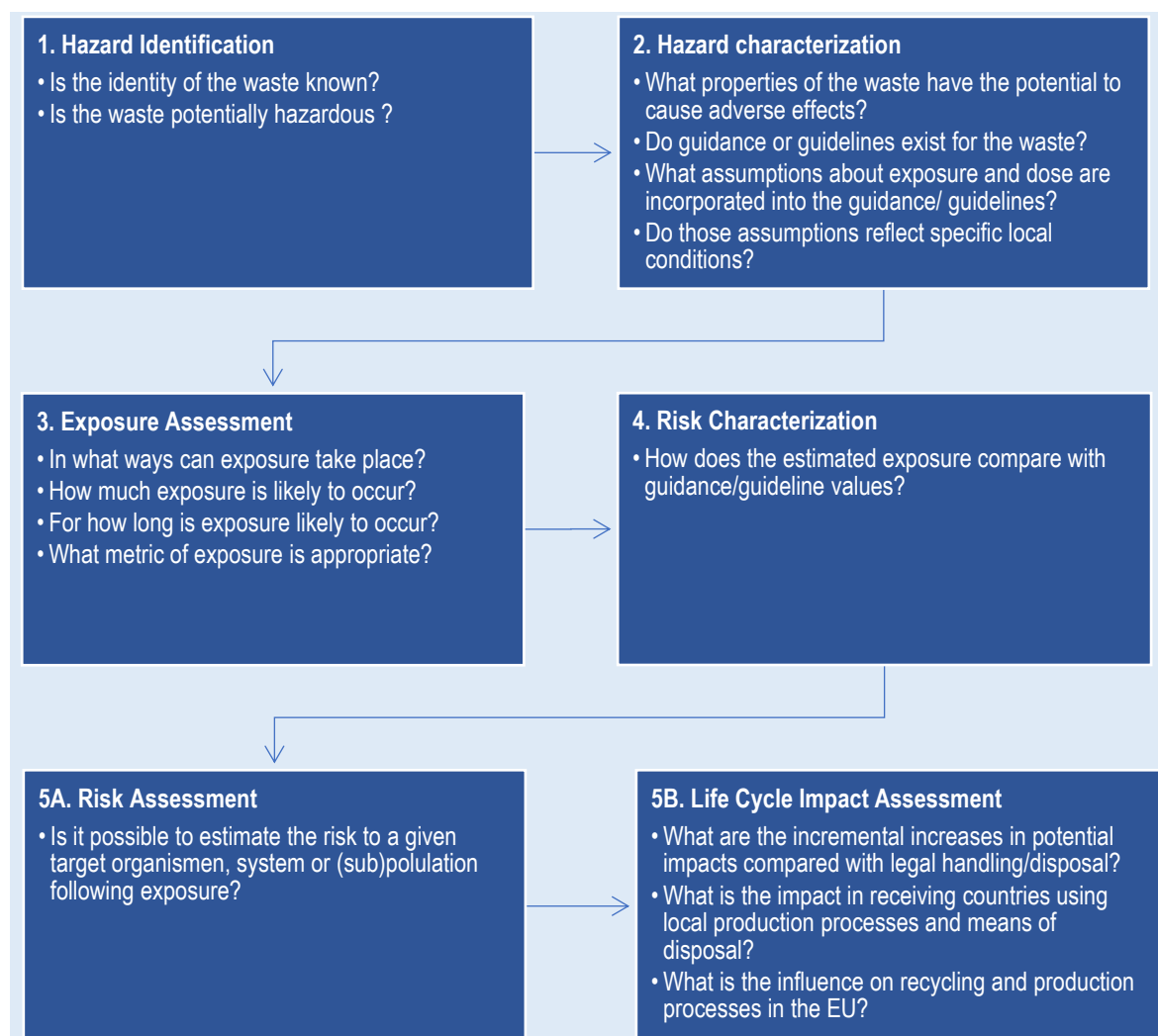


Figure 1: Framework for risk assessments and Life Cycle Impact Assessments(adapted from (WHO 2010)

² Remark: Impact, damage and negative effects are considered synonymous in this report.

Risks and impact linked to illegal transnational waste transports are likely to fall into 3 categories:

1. Health and environmental risks and damage during transport and handling of wastes with unknown compositions.
2. Health and environmental risks or damage on the final destination and associated with final deposition, recovery or recycling.
3. Economic losses.

This study focusses on health and environmental risks caused by individual illegal waste transports (aspects 1 and 2). Any risk or impact assessment starts with a hazard identification. This consists of information with respect to the identity of the waste and its potential hazardous properties (see figure 1). The word “waste” has a legal definition. The first element in shipments is to determine whether the material needs to be considered as waste. The *Basel Convention* and the EU *Waste Shipment Regulation* both have a definition for waste³. As WP 2.3 focusses on the technical research possibilities, the discussion whether material should be considered a waste or not is ignored.

Once the identity of the waste is known, it becomes possible to assess if the identified substances are classified as hazardous. The European *Waste Framework Directive (WFD)* defines 15 hazardous properties (HP1 to HP15) which renders waste hazardous (see Annex 2 for an overview of these properties). The hazard statements or H-phrases attributed according to the *Waste Framework Classification, Labelling and Packaging (CLP) Regulation* (see Annex 1) however contain more specific information with respect to hazardous properties than the hazardous

properties (HP) of the WFD. They hold information with respect to relevant exposures and risks and can be used in a risk assessment or Life Cycle Impact Assessment (LCIA). Since the CLP hazard statements and the WFD hazardous properties are linked, the technical research options between the different legislative frameworks (see Annex 1 Legislative framework and Annex 2 Link between Hazardous Properties and H-phrases) overlap.

2.1 Quality criteria for forensics

Inspections and subsequent technical research have to cover a large variety of different wastes including different unexpected mixtures. ISO 17025 *General requirements for the competence of testing and calibration laboratories* is the main ISO (International Organization for Standardization) standard used by laboratories.

For forensics additional criteria exist (UNODC 2011). Important aspects are the knowledge and expertise of the scientist, expert witness and the reliability of the technical methods used. With respect to the methodology it is important that⁴:

- It can be (and has been) tested.
- It has been subjected to peer review and publication.
- The potential rate of error is known.
- Standards of the technique’s operation exist and are maintained.
- The methodology is generally accepted in the relevant scientific community.

Specific extra criteria for environmental forensics can be extracted from the Dutch Guideline for Sampling and Analysis in Environmental Criminal cases (Public

³ Art 2 of the EU Waste Shipment Regulation refers to art 1 of the EU Directive which states: Waste means any substance or object which the holder discards or intends or is required to discard. Art 2 of the Basel Convention States: Wastes are substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.

⁴ Environmental cases often involve scientific issues and expert opinions, sometimes with multiple experts in different disciplines. In

1993, the United States Supreme Court issued its landmark decision in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993), which made significant changes in the standards for admissibility of expert opinions in federal courts. The criteria originate from this decision and are known as the Daubert criteria (Ries and Burns 2005).

Prosecutor's Office 2007). An overview of these criteria is given in box 1.

Box 1: Guideline for forensics in environmental criminal cases

The Dutch guideline for forensics in environmental criminal cases sets criteria for the technical procedures. The criteria must ensure that procedures are clear and controllable backwards⁵. They apply to 4 research stages:

1. Inspection and administrative control
2. Sampling, analysis and other technical research
3. Laboratory research
4. The compilation of a written report

Inspection and administrative control

During an inspection the first step is to obtain as much as information as possible to about the (hazardous) properties of the waste. Sources of information are:

1. Information from the original producer of the substance or object before it became waste, like for example Safety Data Sheets (SDS), product labels or product fiches, historic and administrative research.
2. Information on the 'waste-generating' manufacturing process, its input substances and intermediate products.

Sampling, analysis and other technical research

If after a visual and administrative inspection the identity of the waste is unclear, additional technical research can be performed. The following selection procedure is advised (see also figure 2):

- If with respect to the sampling objective and the material to be sampled a mandatory methodology is available the sampling should be performed according to this mandatory method.
- If there is no mandatory method available, a standardised method should be selected.
- If there is no standardised method available a code of good practice could be selected.
- Finally if none of these options are available the sampling has to be performed as accurate as possible, so insight is obtained about the representatively and reliability of the results.

For every option the inclusion of checkpoints⁶ is vital, so that the sample results are both reliable and admissible in court. It is advised to sample extra material to facilitate counter analysis by the suspect.

Choice of laboratory

There is a preference for a laboratory that holds an appropriate and up to date accreditation and works with an accredited system and/or uses accredited methodologies. In any case there is a need for the laboratory to work with clear procedures for all different steps in the process so that the provenance and the confidentiality of the results are guaranteed. The choice for a specific laboratory needs to be motivated in a written report. Choices for laboratories with a deviant quality system need extra motivation.

Written report

The report should contain the following information:

- Date, location, time of sampling and individuals present.
- Reason for sampling.
- Nature of the samples, amount of material sampled, number of samples taken and the names of the samplers.
- Sampling strategy, used equipment and packaging methodology.
- Motivation in case the sampling strategy deviates from a prescribed standard.
- For continuity of the evidence: seals, codes, transport (name transporter and destination samples) transfer (receiving body), conservation and pre-treatment of samples.

⁵ These criteria are of a general nature and in line with criteria mentioned in IMPEL's *Step-by-step guidance book for waste shipment inspections* (IMPEL 2012).

⁶ Options for checkpoints are for example: provide a detailed description of the followed procedure, check if results from visual inspections are in line with results from sampling results or secure extra samples so the results can be compared.

- Name of laboratory and used methodology.
- The details of any instructions provided to the laboratory and reasons for research.
- Results and interpretation of the results.
- Motivation if the chosen analytical methodology deviates from the prescribed standard.
- The professional background and qualifications of the person producing the report.
- Signature.

Option 1: Check if a mandatory methodology is available in relevant legislation or permits

No

Option 2: Check if a standardized methodology is available

No

Option 3: Check for a code of good practice or guideline

No

Option 4: Perform technical research as reliable as possible, include checkpoints

Figure 2: Selection scheme for environmental forensics

3. TECHNICAL RESEARCH

3.1 Hazard identification and characterization

Any damage, impact or risk assessment starts with an identification of the potential hazardous properties of the waste involved. An overview of the official technical options to classify waste as hazardous can be found in the technical guidance on the classification of waste (EC 2018/C 124/01 9 April 2018). In the European Union dangerous properties of waste will in practice be judged by the 15 Hazardous properties (HP) defined in legislation. Hazardous properties can be used to determine the risk of handling and transport of wastes. Relevant research questions are given in figure 3.

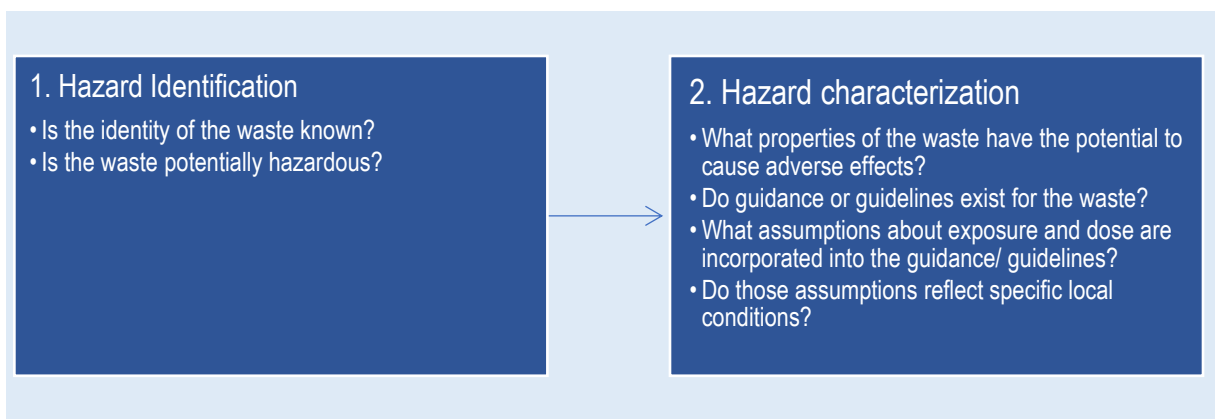


Figure 3: Research questions for hazard identification and characterization

If a waste has been assigned one of the 15 hazardous properties of the *Waste Framework Directive* (see annex 2) and/or hazardous properties defined by the *Basel Convention* hazards and the impact of any event during transport and improper handling are high. The *Basel Convention*, EU legislation and individual national classification systems use different systems in the classification of wastes and hazardous wastes. Most of the classes of the *Waste Framework Directive (WFD)* can find matching classes in the *Basel Convention* system, but in many cases a full match cannot be achieved.

For the inventory of technical research options the WFD is used as a starting point. The background of this choice is that in 2018 the European Commission published an extended *Technical Guidance on the Classification of waste* (EC 2018/C 124/01 9 April 2018). Whereas under the *Basel Convention* the technical guidance's are limited to the hazard

characteristics H6.2 (infectious substances); H12 (ecotoxic) and H13 (capable after disposal of yielding another hazardous material). Work on hazard characteristics H10 (liberation of toxic gases in contact with air or water) and H11 (toxic – delayed or chronic) is still not concluded until future decisions by parties to continue these tasks (Basel Convention 2016) (Basel Convention 2004).

During inspection of waste transports it is not always possible or feasible to perform an elaborate classification of the material. Time pressure and restricted resources are important factors. The first step in any risk and impact assessment is the identification of the material. Every inspection start with the information on the shipping document. The shipping document holds information with respect to the amount of material, the waste identification (waste codes) but also information about the recovery operations or final disposal is present.

3.1.1 On site verification with mobile field equipment

After an administrative and visual inspection mobile field equipment can be used as a first on site verification to determine whether the waste complies with the shipping documents (CEN/TR 16130 June 2011)⁷.

For some HPs the use of field equipment is of extra importance due to the volatile, explosive and oxidising nature (HPs 1, 2, 3, 5, 6 and 12) of the material. It may be the only opportunity to take measurements. In these cases a multigas detector for example can be used before any additional activities with the material are undertaken.

The hazardous properties HP4 and HP8 relate to skin and eye damage. Several properties of the waste may cause it to be irritant or corrosive. One well known the pH⁸.

Waste/substances with a pH ≤ 2 or ≥ 11.5 are considered to be corrosive. Fast identifications of the pH can be obtained in the field. For example by the use of test strips or dedicated special mobile equipment.

Although the accuracy and the reliability of field equipment are developing fast, most of the methods are not validated⁹. To ensure accurate readings, compliance officers should always remember to do the following:

- Consult manufacturer specifications and manuals.
- Conduct periodic calibration tests.
- Conduct calibration any time the equipment may be damaged or is displaying inaccurate results.
- If possible at emergencies, use different types of detectors at the same time to detect differences and to ensure accuracy of results.
- Practice.
- Document all training and equipment maintenance.

Developments in this field are substantial, although some techniques, like a field-portable GC-MS (Gas chromatography combined with mass spectrometry) (Eckenrode 2001) may be still too expensive for routine waste inspections (U.S. Department of Homeland Security 2019).

Practical overviews of field tests can also be found in the European standard CEN/TR 16130 *Characterization of waste- On-site verification* (CEN/TR 16130 June 2011) and in the Interpol manuals about *Pollution Crime Forensics* (Interpol 2014 Volume II).

3.1.2 Sampling methodologies

Where sampling and/or chemical analyses are required the *technical guidance on the classification of waste* (EC 2018/C 124/01 9 April 2018) recommends the following Standards for the classification of waste:

- EN 14899 Framework for the preparation and application of a sampling plan (EN 14899 2005).
- CEN/TR 15310-1:2006 Guidance on selection and application of criteria for sampling under various conditions (CEN/TR 15310-1 2006).
- CEN/TR 15310-2:2006 Guidance on sampling techniques (CEN/TR 15310-2 November 2008).
- CEN/TR 15310-3:2006 Guidance for sub-sampling in the field (CEN/TR 15310-3 November 2006).
- CEN/TR 15310-4:2006 Guidance on procedures for sample packaging, storage, preservation, transport and delivery (CEN/TR 15310-4 November 2006).
- CEN/TR 15310-5:2006 Guidance on the process of defining the sampling plan (CEN/TR 15310-5 November 2006).

The EN 14899 procedures overlap to some extent with procedures mentioned in the

⁷ This section does not include safety information. It is advised that compliance officers are offered safety trainings on a regular basis.

⁸ pH is a scale used to specify how acidic or basic a water-based solution is. Acidic solutions have a lower pH, while basic solutions

have a higher pH. At room temperature (25 °C), pure water is neither acidic nor basic and has a pH of 7.

⁹ Methods for validation can be found in (ISO 5725 1994).

Interpol manuals (Interpol 2014 Volume I) (Interpol 2014 Volume II). Procedures mentioned in EN 14899 focus on the characterization of the waste, whereas procedures mentioned in the Interpol Manuals focus on ways to determine actual effects on the environment and human health in case of illegal releases.

To obtain reliable results from a sampling procedure the samples should be representative for the waste composition. In waste sampling this may be complex since pollutants may be distributed non-homogeneously throughout the waste (Stelling and Sjerps, Heterogeneity of contaminants in solid waste materials sampled for compliance testing 2005) (Stelling and Biezeman, Sampling Strategies in environmental criminal cases 2010). Sampling procedures are

responsible for the largest uncertainty in the total research process in case materials are heterogeneous. Measurement uncertainties in subsequent laboratory research tend to be much lower¹⁰. A way to deal with the heterogeneity of waste is to increase the number of samples. This invariably leads to higher sampling and analysis costs. The heterogeneous character of waste invokes the necessity to balance the desired reliability with the financial input.

For large amounts of discrete (countable) units the hypergeometric distribution (see table 1 for an example) may be used to limit the number of samples. The hypergeometric distribution originates from drugs and food sampling (2002/63/EC 11 July 2002) (United Nations 2009)¹¹.

Table 1: Hypergeometric distribution

Total number of units present	Number of units to be examined to state with a 95% reliability that at least 50% of the total amounts of units present is non-compliant			Number of units to be examined to state with a 95% reliability that at least 80% of the total amounts of units present is non-compliant		
	0 negative ^A	1 negative	2 negative	0 negative	1 negative	2 negative
10	3	5	7	7	9	10
20	4	6	8	9	13	16
30	4	7	9	10	15	19
50	4	7	10	11	17	23
80	5	7	10	12	19	25
100	5	7	10	12	20	26
200	5	8	10	13	21	28
400	5	8	11	14	22	29

^A Number of negative (compliant) results after examination of the selected unit.

¹⁰ Literature mentions that up to 90% of the total measurement may be caused by the sampling process (Ramsey, Ellison and Rostron 2019).

¹¹ A tool is available on the website of the European Network of Forensic Science Institutes (ENFSI). See <http://enfsi.eu/documents/forensic-guidelines/> ENFSI DWG Qualitative sampling calculator (2018-07-20).

3.1.3 Laboratory research; physical testing, chemical analysis and toxicity tests

In annex 3 of the *Technical guidance on the classification of waste* (EC 2018/C 124/01 9 April 2018) approaches are given to determine hazard properties (HP1 to HP15). For the actual test methods there is a general reference to the *Guidance on the Application of the CLP Criteria* (ECHA 2017). No test method is available for HP9: *Infectious*. For the assessments of HPs 4, 5, 6, 7, 8, 10, 11 and 13 the procedure is:

- Identification of the individual substances in the waste.
- Their classification.
- Reference to concentration limits in Annex III to the Waste Framework Directive.

For some HPs it is possible to perform tests on biological systems to determine the overall toxicity. Advantage of this approach is that the toxicity of the complete (unknown or partly unknown) mixture is tested. Note that test methods given in the *Test Methods Regulation* that rely on animal testing are not appropriate for waste testing¹².

Further in-vitro¹³ methods may be available from other sources, such as the European Union Reference Laboratory for alternatives to animal testing¹⁴.

Whenever a hazardous property of a waste has been assessed by a test and by using the concentrations of hazardous substances as indicated in Annex III to the Waste Framework Directive, the results of the test should prevail.

With respect to HP 7: *Carcinogenic* testing is neither envisaged for waste nor for mixtures in

the CLP Regulation¹⁵. Mutagenicity tests (HP 11) are considered in many cases to be a suitable indicator of potential carcinogenicity. With respect to HP 10: *Toxic for Reproduction* only limited in-vitro¹³ options are available.

The assessment of HP9 depends on a reference to categories of specific risk groups of organisms according to their potential to cause and spread infection and their potential clinical treatment.

The World Health Organization (WHO 2004) provides a widely recognized system categorising organisms. There are no test methods given. The assessment of a waste that may possess the HP9 property depends on a simple, systematic evaluation described in the *Draft guidance paper on hazard characteristic H6.2 (infectious substances)*¹⁶ (UNEP 2004).

The *Technical guidance on the classification of waste* (EC 2018/C 124/01 9 April 2018) contains calculation rules to determine if HP14: *Ecotoxic* is applicable. The rules are based on the substances with the hazard statements H400, H411, H412 and H413 present in the waste. All these hazard statements relate to aquatic toxicity. No criteria exist for the terrestrial environment. Ecotoxicity can also be determined by biotests (see for example (NEN-EN 14735 august 2005)). There is within the EU currently no consensus with respect to the use of biotests (BIO by Deloitte 2015). Until further EU guidance is available, Member States can decide on a case-by-case basis on the acceptability and interpretation of results of biotests.

¹² See Annex to the LoW (point 2, indent 2): A hazardous property can be assessed by using the concentration of substances in the waste as specified in Annex III to Directive 2008/98/EC or, unless otherwise specified in Regulation (EC) No 1272/2008, by performing a test in accordance with Regulation (EC) No 440/2008 or other internationally recognised test methods and guidelines, taking into account Article 7 of Regulation (EC) No 1272/2008 as regards animal and human testing.

¹³ An in vitro test is performed or taking place in a test tube, culture dish, or elsewhere outside a living organism.

¹⁴ <https://eurl-ecvam.jrc.ec.europa.eu/>

¹⁵ Toxicity research to determine carcinogenic properties of substances/materials still largely depend on long term animal testing.

¹⁶ HP9 is equivalent to H6.2 in the Basel Convention

3.2 Exposure assessment and risk characterization

If a waste has been assigned one of the 15 hazardous properties (HPs) of the Waste Frame Directive and/or hazardous properties of the Basel Convention the impact of any event during transport and improper handling, recovery or disposal operations in receiving countries is high. Unnecessary emissions of substances are likely to occur at some point. The methodology is applicable to non-hazardous wastes as well. Relevant research questions are given in figure 4.

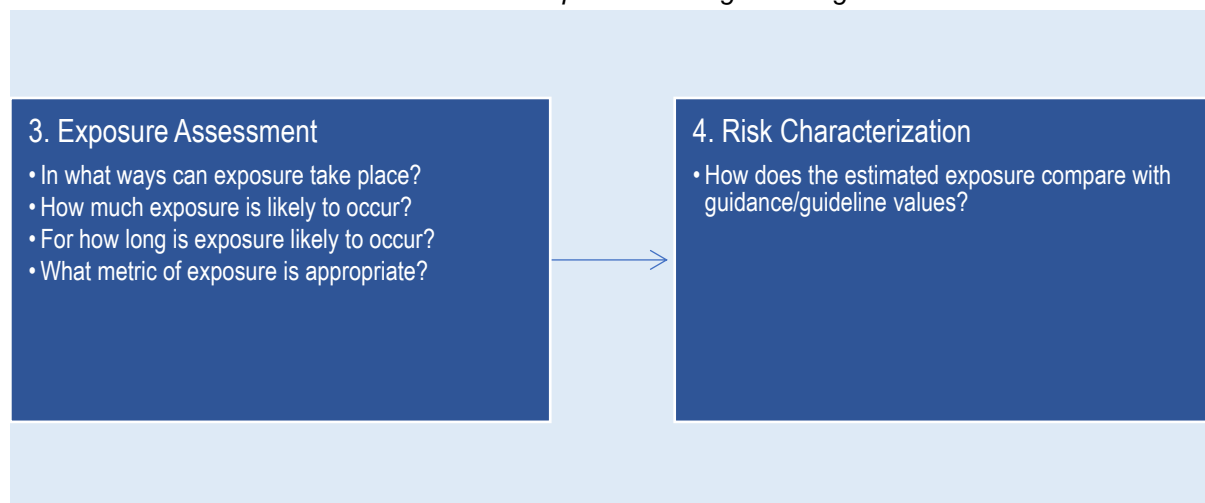


Figure 4: Research questions for exposure assessment and risk characterization

An exposure assessment is used to determine whether contact with a potentially (hazardous) chemical is possible and, if so, how much, by what route, through what media and for how long. Since hazard and risk characterization depend upon the route (oral, inhalation, dermal) and duration (short-term, medium-term, long-term) of exposure, knowledge of how people and the environment may be exposed is relevant.

Exposures can be measured directly, estimated using models or generalized from existing data. Of the three methods, estimating exposures from existing data can often be the simplest approach. However, data are not always available or entirely relevant to the risk assessment at hand. Measurements, on the other hand, generally provide the most accurate and relevant data, but may be difficult to collect, obviating their use for many risk assessments. The representativeness of exposure measurements depends on many factors that are specific to the chemical or material of interest. These factors include the availability, performance and sensitivity of

appropriate exposure measurement devices, the size and activity patterns of the potentially exposed population, the contact rate and duration of exposures and the media through which exposures generally occur. Information about activity patterns, contact rates and exposure durations as well as other information about the potentially exposed population can be obtained through surveys and questionnaires.

The duration of exposure is a critical element in assessments and estimations of health risks, as the relevant period of exposure is defined by knowledge or theory of the mechanisms of injury or disease. Single and short-term exposures over minutes, hours or a day are relevant for chemicals that have an immediate or rapid adverse effect on the body at certain concentrations. Examples are wastes with hazardous properties HP4, HP6 and HP8. Medium-term or intermediate exposure is important for chemicals that are thought to exert adverse effects over a period of contact that ranges from weeks to months. For chemicals that pose a hazard as a result of

cumulative or long-term low-dose exposure, long-term average exposures are most relevant for characterization of adverse effects. Examples are wastes with the hazardous properties HP7 and HP10. The WHO Toolkit for human health risk assessments can be helpful in exposure assessments. (see <https://apps.who.int/iris/handle/10665/44458>).

Besides the above-described traditional exposure assessments, the use of biological markers is another method to evaluate human exposure. Biological markers of exposure are considered to be measures of the internal dose, whereas exposures describe the contact with a chemical at the boundary between an individual (e.g. skin, mouth or nostrils) and the environment, food or consumer products.

For environmental exposures assessments the OECD has developed a toolkit (See <https://envriskassessmenttoolkit.oecd.org/Default.aspx?idExec=328298b4-4f36-4cb9-b6c3-dfcafedbddcd>).

In practice an exposure assessment may be difficult to realise by compliance officers. Practical solutions can be found in the Interpol manuals (Interpol 2014 Volume I) (Interpol 2014 Volume II). As indicated in these manuals a detailed description of the situation (crime scene) is important. Photos and videos to demonstrate that emissions and exposures have taken place can be useful, if possible supplemented by results from mobile field equipment. See pictures below for examples.



Emissions of corrosive calcium dust from steel slag (Photo NFI)



Alkaline leachate from steel slag (Photo NFI)



Toxic residues from plastic waste packaging (photo NFI)



Toxic residues from plastic waste packaging (photo NFI)

3.3 Risk assessment and Life Cycle Impact Assessment

For impact assessments two tools are available: Risk assessment and Life Cycle Impact Assessment (LCIA). Between these tools there are several areas of overlap (Csiszar 2017) (Harder 2015). The two approaches however answer different questions, have different perspectives and are applied in differing ways. There has been a recognition for the need for risk assessment and environmental sustainability-based approaches like Life Cycle Impact Assessments to be used together. In figure 5 the relevant research questions of the two methodologies are given.

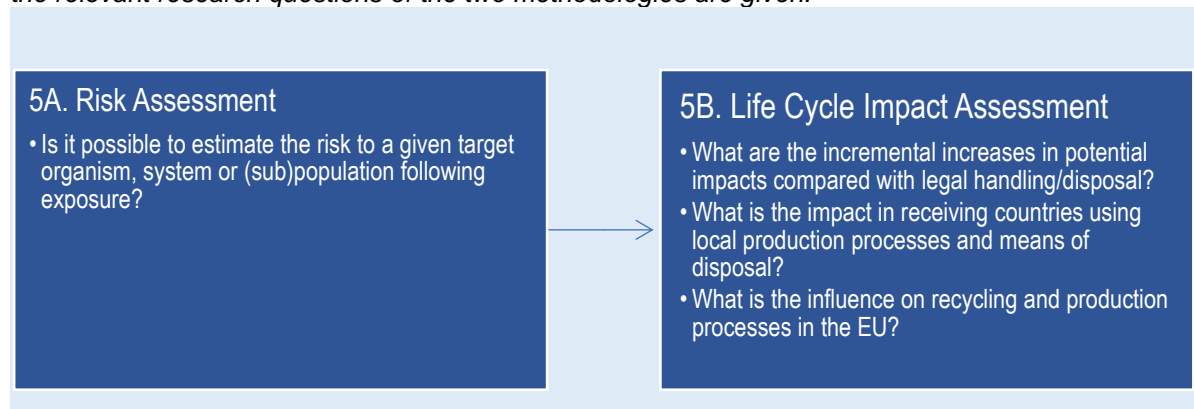


Figure 5: Research questions for a risk assessment and Life Cycle Impact Assessment

After identification of the (hazardous) characteristics and exposure estimates, a risk or Life Cycle Impact Assessment can be performed. The word “risk” has the following definition:

$$Risk = Probability \times Severity\ of\ impact$$

An implication of this formula is that a risk is not just determined by the potential hazardous properties of the waste (EC 2018/C 124/01 9

April 2018) but that the likelihood of specific scenario’s is important as well (see figure 6).

Risk assessment refers to methods and techniques that evaluate hazards, exposure and harm posed by a limited set of chemicals in a specific situation (WHO 2010) (Saouter and et al 2018) (Fazio and et al 2018).

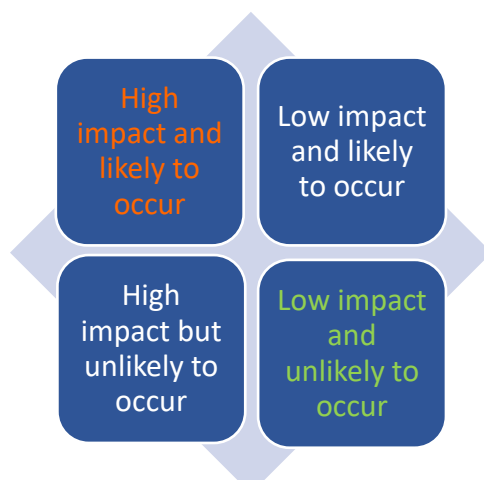


Figure 6: Relation between severity of an impact and the likelihood of specific events to occur

Approaches for unified risk assessment methodologies after releases of hazardous substances can be found in *Development of an assessment methodology under Article 4 of Directive 2012/18/EU on the control of major-accident hazards involving dangerous substances* (AMEC December 2014). This document describes methodologies developed in the Czech Republic (Hazard and Vulnerability Index), Sweden (Environment-accident index), UK (environmental risk assessment approach) and Spain (environmental risk assessment approach). All of these methodologies have score lists to divide the effects of an incident into impact categories of different gravities. In addition the Slovak methodology for Environmental Impact Assessment can be mentioned¹⁷ (Ovare and Fic oktober 2014). The guideline describes procedures for the construction of a detailed environmental risk assessment and provides a tool to estimate the appropriate amount of financial liability for environmental damage.

Life Cycle Impact Assessment (LCIA) is a tool used to quantitatively analyse the life cycle of products and activities within the context of environmental impact. The concept has been under development within the European Union over the past years (Fazio and et al 2018). In a LCIA the total life cycle of a product or activity is considered; from the extraction of resource materials onto the waste and waste treatment stage.

The result of a LCIA-study is an environmental profile of a product or activity: a 'score list' with environmental effects. The environmental profile or environmental footprint shows the largest environmental problems caused by a product, and at which stage(s) in the life cycle these problems are caused. Also, the consequences of different alternatives can be made visible.

To create an environmental footprint for illegal waste transports the 16 LCIA impact categories (Huijbregts, et al. 2017) (EU-JRC 2010) (Zampori, et al. 2016) (Saouter, Biganzoli, et al. 2018) (Sala, Crenna, et al. 2017) proposed by the Joint Research Centre of the European Commission are used (see table 2). An impact category is also referred to as a midpoint impact category. In a midpoint impact category the emissions and release of a specific substance are high enough to cause changes in the natural environment. For higher emissions and releases 9 damage pathways are defined leading to three types of endpoint damage. These are damage to human health (expressed predominantly as disability adjusted life years (DALY)), damage to ecosystems (expressed as potentially disappeared fraction of species (PDF) and damage to resource availability (in this study expressed in euro).

Multiple models are available to estimate the emissions and releases in the different impact categories (see (Fazio and et al 2018) (EU-JRC 2010) (Huijbregts, et al. 2017) (USEtox® 2017) and both commercial and free online computer programs are available. See for example <https://usetox.org> or <https://www.rivm.nl/documenten/recipe2016cfs20161004>. The European Commission hosts a platform on life cycle assessments (<https://eplca.jrc.ec.europa.eu/>) to keep track of the latest developments in this area. For example USEtox is the UNEP/SETAC scientific consensus model for characterizing human toxicological and ecotoxicological impacts of chemical emissions in life cycle assessments.

Once the emissions and releases caused by recovery or disposal ways of a specific waste are known, they can be scored in one the predefined midpoint categories mentioned in table 2, thus creating an environmental footprint.

¹⁷ An English summary was kindly provided by Martin Jakuš of the Slovak Environment Agency.

Table 2: Life Cycle Impact Assessment, midpoint impact categories, damage pathways and endpoints of protection

Midpoint impact category	Damage pathways	Endpoint area of protection
1. Particulate matter	1.Increase in respiratory disease	1.Damage to human health
2. Photochemical ozone formation		
3. Ionizing radiation	2.Increase in various types of cancer	
4. Stratospheric ozone depletion (upper layers)		
5. Human toxicity (cancer)		
6. Human toxicity (non cancer)	3.Increase in other diseases/causes	
7. Global warming (climate change)		
8. Water scarcity	4.Increase in malnutrition	
9. Acidification	5., 6. And 7. Damage to freshwater, Terrestrial or marine species	2.Damage to ecosystems
10. Ecotoxicity		
11. Freshwater eutrophication		
12. Terrestrial eutrophication		
13. Land use/transformation		
14. Marine eutrophication		
15. Mineral resources	8.Increased extraction costs	3.Damage to resource availability
16. Fossil resources	9.Increased oil/gas/coal/energy costs	

The emissions and releases of the different midpoint impact categories are expressed in different units. An overview of the units is given in table 3. The impact on the midpoint category climate change (no.7) is for example expressed in kg CO₂ equivalents¹⁸. Midpoint impact category water use (no.8) is expressed in cubic meters. The different units make the interpretation of a ‘raw’ environmental footprint rather difficult. A reference framework with the impact of regular emissions and releases is lacking.

To facilitate the interpretation of an environmental footprint normalization factors have been designed (see table 3). The estimates of emissions and releases are multiplied by normalization factors in order to calculate and compare the magnitude of their contributions to the impact categories relative to a reference unit. The reference unit typically is the pressure related to that category caused by the emissions over one year of a whole country or an average citizen. As a result, dimensionless, normalised results are

¹⁸ Background of the expression in equivalents is that not every substance has the same impact. A kilogram of methane gas for

example has more impact on climate change than a kilogram of CO₂.

obtained. In table 3 global normalization factors (NF) for citizens are given.

Weighting (Sala, Cerutti and Pant 2018) is an additional optional step that may support the interpretation and communication of the results. In this step, environmental footprint results are multiplied by a set of weighting factors which reflect the perceived relative importance of the impact categories considered. Weighting requires making value judgements as to the respective importance of the impact categories considered. These judgements may be based on expert opinion, cultural/political viewpoints, or economic considerations (JRC European Commission 2012) (Sala, Cerutti and Pant 2018). After normalization and weighting an environmental footprint can be created that is uniform but the interpretation is still not straightforward. In this context, environmental pricing or monetization can be seen as a further method for mutually weighting environmental themes and combining environmental impacts into a single, uniform indicator. In 2017 an *Environmental Prices Handbook* for the European market has been developed (CE Delft 2018). The environmental prices developed in this handbook are derived from damage costs and are consistent with standard practice in welfare economics. By calculating and valuing the damage caused by environmental pollution (or other such interventions) with respect to a range of endpoints, a value can be assigned to the additional overall damage caused by an additional kilogram of a given emission (or equivalent). The environmental prices reported here in WP 2.3 are the average prices for the year 2015 per kilogram emission (and other units) from an average source at an average location (with average population density and average income). Environmental prices are rough-and-ready estimates that are not necessarily valid in specific situations. Parallel with the publication of this *Environmental Prices Handbook*, an online tool has been launched where users can look up the prices.

It is available at www.cedelft.eu/en/environmental-prices and can be used free of charge. It contains environmental prices for over 2.000 environmental pollutants. The online toolkit is specific for the Dutch market. It should be noted that there is still discussion with respect to different quantification methods. Different relative weights to the various impact categories may be given and may result in different conclusions. Also other monetization strategies exist, such as the *Environmental Priority Strategies* (EPS) method developed in Sweden (Steen, 1999) (Pizzol, et al. 2015), the UN *System of environmental economic accounting* (SEEA) <https://seea.un.org/content/homepage> and discussions going on under the heading of *Natural Capital* <https://naturalcapitalforum.com/about/> (POSTnote 2016).

Besides the more straightforward interpretation of the results, monetization of the impact of environmental damage of illegal waste trafficking has the advantage to facilitate the link between aspects like economic damage and fines. The UK for example has a sentencing guideline for environmental offences (Sentencing Council 2014) in which criteria are given to classify unauthorised or harmful deposits, treatment or disposal of waste and illegal discharges to air, land and water in 4 different categories with different fines. In this respect the Slovak Guideline methodology for *Environmental Impact Assessment* (Ovare and Fic oktober 2014) is also interesting.

Being an illegal activity the impacts of illegal transnational waste trafficking and subsequent were about of the wastes transported, will not be a part of a regular life cycle impact assessment. In individual cases both risk assessments and LCIA can have added value. In cases where actual risks exist and environmental damage has been caused a risk assessment seems more natural. In situations

where the impact of improper recovery or disposal processes need to be compared with regular ones a LCIA will be superior.

Table 3: Units, normalization factors, weighting factors and environmental prices per impact category

Impact category	Unit ¹⁹	global NF per person ²⁰	Weighting factor ²¹	Environmental prices ²²
1. Particulate matter	kg PM10 equivalents	7.18E-04	8.96	€ 39.2
2. Photochemical ozone formation	kg non-methane volatile organic compounds (MVOC) equivalents	40.6	4.78	€ 1.15
3. Ionising radiation	kBq U-235 equivalents	4220	5.01	€ 0.0461
4. Ozone depletion	kg CFC equivalents	0.0234	6.31	€ 123
5. Human toxicity, cancer	kg 1,4 dichlorobenzene (DB) equivalents ²³	3.85E-05	2.13	€ 0.0894
6. Human toxicity, non-cancer	kg 1,4 dichlorobenzene (DB) equivalents ²³	4.75E-04	1.84	€ 0.0894
7. Climate change	kg CO ₂ equivalents	8400	21.06	€ 0.0566
8. Water scarcity	m ³ water equivalents of deprived water	11500	8.51	€ not available
9. Acidification	mol H ⁺ equivalents	55.5	6.2	€ 7.48
10. Ecotoxicity	kg 1,4 dichlorobenzene (DB) equivalents ²³	11800	1.92	€ 0.0361 (freshwater) € 8.69 (terrestrial) € 0.00739 (marine)
11. Freshwater eutrophication	kg P (phosphorus) equivalents	0.734	2.8	€ 1.86
12. Terrestrial eutrophication	mol N (nitrogen) equivalents	177	3.71	€ not available
13. Land use	m ² *year	1.40E+06	7.94	€ 0.126
14. Marine eutrophication	kg N (nitrogen)	28.3	2.96	€ 3.11
15. Resource use, minerals and metals	kg Sb (antimony) equivalents	0.0636	7.55	€ not available
16. Resource use, fossils	MJ	65300	8.32	€ not available

¹⁹ Results are expressed in equivalents relative to a reference substance.

²⁰ The normalization factors (NF) express the total global impact of a person for a certain impact category in a reference year.

²¹ Weighting is used in the creation of Environmental Footprints to support the identification of the most relevant impact category.

²² Prices for the year 2015 are given (CE Delft 2018). The prices are for the reference substance in a specific category.

²³ In more recent literature 1,4 dichlorobenzene equivalents have been replaced with Comparative Toxic Unit (CTU) for either humans or ecosystems.

4. CASE STUDIES

In chapter 3 the technical options for a risk assessment and a Life Cycle Impact Assessment are summarised. Chapter 4 will focus on the use of the suggested methodology in illegal waste transports. Case studies are delivered by WasteForce partners. In most of these cases originally no risk assessment or Life cycle Impact Assessment was performed, or only partial. Based on information available the options will be discussed. For every case the scheme in figure 1 is followed as much as possible. Results of waste inspections are the basis of each assessment (see Annex 1 of the WSR (EC No 1013/2006 14 June 2006) for the notification document for transboundary movements/shipments of waste. The outcomes are indicative. In some cases the case description did hold incomplete information with respect to the (hazardous) substances present in the waste, in other cases the information from existing LCIA studies was incomplete or did not completely match with the waste or expected waste treatment. The following materials were evaluated:

- 1. Reclaimed asphalt*
- 2. Paper, paperboard and paper product wastes*
- 3. Ship breaking*
- 4. End of life vehicles with additional loading*
- 5. Wastes from baking and confectionery industry*
- 6. Mixed plastics; mixture of different wastes*
- 7. WEEE; used electronics*

4.1 Export of reclaimed asphalt

Case description:

A professional market player has exported 2.779 ton non thermal cleaned asphalt waste from the Netherlands to Lithuania for processing and recovery (Court of Rotterdam 2018a). The receiving Lithuanian company did not hold the necessary permits. As a consequence there was an illegal transnational shipment of waste with the argument to circumvent the Dutch limit for polycyclic aromatic hydrocarbons (PAH) or tar containing asphalt, set to protect the environment and human health. In the Netherlands reclaimed asphalt is categorized as tar-containing if the concentration of the sum of a number of PAH (10 in total) exceeds 75 mg/kg dry matter.

The fact that the transported material is an industrial waste is not disputed. By transporting a waste, referred to as asphalt granulate (bituminous material code B2130 (annex IX to the Basel Convention) from the Netherlands into Lithuania the suspect has deliberately, carried out operations as set out in art 2, under 35 (sub e) of the Waste Shipment Regulation (EC no. 1013/2006). The shipping documents unduly mentioned recovery operations code R13: Accumulation of material intended for any operation numbered R1 to R12. Within the meaning of the Waste Shipment Regulation this was in Lithuania impossible. Moreover the R13 code should always be used in conjunction with another R code. Suspect is convicted and fined € 50.000,-



Photo originates from the internet

Hazard identification and characterization

The identity of the material can be derived from code B2130 (Basel Convention). It refers to bituminous material (asphalt waste) from road construction and maintenance, not containing tar. Meaning the concentration of benzo(a)pyrene does not exceed 50 mg/kg ((EC) No 1013/2006 14 June 2006).

Benzo(a)pyrene is a polycyclic aromatic hydrocarbon (PAH) and considered a marker substance for the toxicity of PAH mixtures.

If the concentration had exceeded 50 mg/kg, code A3200 (hazardous) had been applicable.

The alternative waste code in the European List of

Waste is 17 03 01*. This code is applicable if more than 0.1% of coal tar is present. Below this limit a waste material can be reused as construction material or intermediate product. In this particular case there is no dispute with respect to the composition of the waste. No additional technical research was performed. Had the suspicion been that the waste was hazardous a sampling and subsequent chemical analysis might have been helpful. Although from literature it is known that the determination of the exact levels of coal tar can be difficult, because layers with different

concentrations of benzo[a]pyrene can be present (Natural Resources Wales and others 1st edition 2015). The H-phrases for benzo[a]pyrene²⁴ are:

- H317 *may cause an allergic skin reaction*
- H340 *May cause genetic effects*
- H350 *Carcinogenic*
- H360 *May damage fertility or unborn child*
- H400 *Very toxic to aquatic life*
- H410 *Very toxic to aquatic life with long lasting effects*

Exposure and risk characterization

Exposure can take place during handling, transport, recycling and recovery operations in Lithuania. Although the waste contains PAH the material is considered non-hazardous. The expected short term exposure during handling and transport are considered not relevant. Depending on the ways the material is treated in Lithuania exposure to PAH in fumes and dusts emitted during milling and work with reclaimed asphalt can take place through inhalation (Enell and et al 2010) (Turk, Mladenovic and et al 2014) (Huang, Parry and et al 2012) (McNally and et al 2012). Skin exposure and oral uptake can take place through insufficient hygienic conditions. Effects of long-term exposure vary between irritation of the skin and eyes to lung, bladder and skin cancer (H317 and H350).

Through leaching and uncontrolled spreading the PAH can contaminate the underlying soils and groundwater (H400 and H410). Substantial amounts of PAH can leach from temporary stockpiles. Since this an attempt for an illegal transport the probability that this waste will be reused not in accordance with procedures is high.

Risk assessment and Life Cycle Impact Assessment

No information is available about the Lithuanian recycle options. For a quantitative assessment the concentration levels of PAH are needed. To fill in this data gap levels from another more or less similar NFI case were taken in which an average of 450 mg/kg PAH was measured²⁵. The concentration of benzo(a)pyrene in this case was 33 mg/kg. Information about emissions originate from literature (Arm, et al. 2017). Recycling of tar contaminated reclaimed asphalt (bound or unbound) in the surface layer of a road results in high emissions (40-100% of the original PAH content) due to leaching to surface waters and other surroundings and emission in fumes during hot recycling. If tar contaminated reclaimed asphalt is recovered in subsurface constructions the emissions will be low (1-2% of the total PAH content). Leaching during temporary storage will have the lowest impact. In this example the worst case scenario is used and a 100% PAH emission is assumed. Information from the *Environmental Prices Handbook* indicate that benzo(a)pyrene is the most expensive PAH (being the most toxic) with a price of €43.30 per kg for a soil emission. A total amount of 2779 ton with a benzo(a)pyrene concentration of 33 mg/kg leads to 92 kg benzo(a)pyrene emission and an impact that is equivalent to € 4000,- (CE Delft 2018). Fluoranthene is the next expensive PAH in line with a price of € 0.026 /kg for a soil emission. A concentration of 143 mg/kg fluoranthene leads to a maximum emission of 397 kg. The damage is equivalent to €10, - which is insignificant. Total damage is estimated to be €4000,- in (terrestrial) ecotoxicity. This amount is used in the environmental footprint (see figure 7).

²⁴ Information derived from ECHA (European Chemicals Agency).

²⁵ For the individual PAH the figures are: naphthalene 9 mg/kg; anthracene 25 mg/kg; phenanthrene 110 mg/kg;

fluoranthene 143 mg/kg; benzo(a)anthracene 103 mg/kg; chrysene 40 mg/kg; benzo(a)pyrene 33 mg/kg; benzo(ghi)perylene 12 mg/kg; benzo(k)fluoranthene 16 mg/kg; Indeno(1,2,3-cd)pyrene 16 mg/kg.

4.2 Export of contaminated used papers

Case description:

A company has imported contaminated waste paper from Ireland and UK to the Netherlands over multiple years. Subsequently the waste paper was exported from the Netherlands to China for recycling without sorting. Suspect is sentenced to one year of imprisonment. The court ruling states that the waste paper contained plastics and other materials that are not an inherent part of waste paper. As a consequence the waste should in principle be considered as a waste mixture, not suitable for recycling. The exact amount of non-inherent material present is not relevant and as a consequence the representatively of the sampling procedure is considered not relevant (Criminal Court Zeeland-West-Brabant 2017)



Photo: NFI

Hazard identification and characterization

Focal point in the case was whether this material is within the definition of Annex III of the WSR (green list). Annex III refers to Annex IX of the Convention of Basel in which code B3020 *paper, paperboard and paper product wastes* is recorded, provided the materials are not mixed with hazardous wastes.

Photographs, witness statements and a sequent sampling procedure indicate that the paper waste contained a substantial amount of other materials, predominantly plastics. These materials are not considered to be an intrinsic part of waste paper. The court ruled that the WSR does not allow any contamination within code B3020 except for substances that are an inherent part of the waste. Not inherent contamination can hamper recovery and recycling operations (EN 643 2013).

This line of reasoning makes a sampling and analysis procedure in principle redundant. In the original case a detailed characterization of the material was available and because insight in the exact composition of the material is relevant for risk assessments and Life Cycle Impact Assessments the sampling procedure is described below. The amount of material 2000 ton. Since the material consisted of discrete countable units (bales) the sampling procedure was performed according to the hypergeometric distribution mentioned in table 1. Out of 48 bales 9 were selected for examination. The selected material was sorted out and examination revealed the presence 14.8% contamination. The hypergeometric distribution was used to state with a 95% reliability that at least 23 of the total of 48 bales contain more than 10% contamination²⁶.

²⁶ Data originate from NFI.

Exposure and risk characterization

No hazardous substances are found to be present. There is no direct exposure to potential hazardous substances to be expected. Environmental benefits of paper recycling are (PRN 2019) (BAT pulp, paper and board 26 september 2014) (Jonkers 2012):

- Reduction of the amount of waste. It reduces the pressure on landfill capacity and reduces greenhouse gas emissions from paper decaying in landfills.
- Reduction in the use of new ground materials.
- Reduction in energy and water use.

Risk assessment and Life Cycle Impact Assessment

In this situation a Life Cycle Impact Assessment will provide more information with respect to the impact than a risk assessment. Under regular circumstances waste papers are recycled (Environmental resource management 2012). No information is available with respect to the treatment options in China. Given the information that the material is unsuitable for recycling different options for waste treatment are possible (Joint Research Centre 2007). Uncontrolled landfilling was chosen as a worst case

scenario. It has a large global warming potential due to high methane emissions. The environmental impact of uncontrolled paper and board landfilling is estimated to be € 430, - per ton of waste (impact category climate change). The environmental benefits of recycling corrugated board or newsprints are estimated to be around € 250, - per ton of waste (around € 100, - per ton in the impact category climate change and € 100, - in the category respiratory inorganics). For polyurethane (PE) plastics these figures are € 45, - for uncontrolled landfilling (€ 40, - in the impact category climate change and € 5, - in the category nature occupation). Recycling has a beneficial impact of around €380, - per ton of waste (mainly due to the impact categories climate change (€180, - per ton) and respiratory inorganics (€ 200, - per ton)). In summary landfilling 1990 ton of paper and board with 20 ton of plastics (assuming this is PE (polyurethane)) has an impact on climate change that is equivalent to around 1 million euro. The impact on particulate matter (respiratory inorganics) is equivalent to €200.000, -. The costs for land occupation are estimated to be €100, - which is negligible. The figures for impact on climate change (CO₂) and particulate matter are part of the environmental footprint in figure 7.

4.3 Ship-breaking

Case description (Court of Rotterdam 2018b):

In 2012 four ships were transferred from Rotterdam (the Netherlands) and Hamburg (Germany) harbours to beaches in India (Alang), Bangladesh (Chittagong Roads) and Turkey (Aliaga) to be demolished. The ships are regarded as waste, as referred to in the WSR (EC 1013/2006) and the Basel Convention. All ships were refrigerator vessels (reefers). The shipping company was subject to punishment by a fine of € 50.000, - and blacklisted for a year.



Photo originates from YouTube: National Geographic Where ships go to die, workers risk everything, published April 16, 2014

Hazard identification and characterization

Public prosecution designated the ship as a mixed waste according to the *Waste Shipment Regulation* EC No 1013/2006 composed of hazardous and non-hazardous wastes²⁷. The reefers are all build in 1984 and sold to be demolished and to recycle the steel. The Court has accepted the fact that only limited research was performed to determine the presence of hazardous substances. An expert witness has stated that asbestos and refrigerants are present in all marine vessels build before 2002. The chlorofluorohydrocarbon (HCFC) R-22 (H phrase H420: *Harms public health and the environment by destroying ozone in the upper atmosphere*) is used in the pantries and air-conditioning. In the reefers R-22 is also used in the cooling/freezing system of

the cargo. According to previous inspections ship 1 contained 1875 kilo R-22 and ship 2 contained 1833 kilo R-22. Ship 3 and 4 should have contained similar amounts. HCFC (H420 and HP14: *Ecotoxic*) and asbestos (H350 and HP7: *Carcinogenic*) are mentioned in Annex V of EC No 1013/2006 (*Waste Shipment Regulation*). The Court has stated that the exact amount of hazardous substances is irrelevant.

Other in the writ of summons mentioned wastes like batteries and bilge oils probably were present because the ships were still operational and nowhere is mentioned that these wastes were removed. Since additional information is lacking about the amount or composition of these materials/wastes the Court did not make a guilty judgement with respect to these materials. The Court considers the ships as a hazardous waste that due to the presence of different types of

²⁷ From the 31rd of December 2018 new European ships and EU-flagged ships going for dismantling must have an inventory of hazardous materials (IHM) verified by the relevant administration or authority and specifying the location and approximate quantities. The European Maritime Safety Agency (EMSA 2016) has

developed a best Practice Guidance on the Inventory of Hazardous Materials. The guidance contains information on the background information that should be available, quality criteria, the performance of a visual inspection and sampling and analysis.

hazardous wastes cannot be classified under one single entry in Annex V of the Waste Shipment Regulation.

Exposure and risk characterization

It is a fact of common knowledge that by ship beaching and demolishment on the beach, sea water, ground water and air are contaminated with hazardous materials. Ships are demolished by hand by untrained employers, lacking the knowledge and expertise and thus unable to recognise dangerous materials and to prevent unnecessary exposures and emissions. Protective clothing and tools are not available²⁸ (see also (Science for Environment Policy 2016)).

The secretariat of the Basel Convention has published *Technical guidelines for the environmentally sound management of the full and partial dismantling of ships* (Secretariat of the Basel Convention 2003) to prevent exposures and emissions.

Risk assessment and Life Cycle Impact Assessment

The 4 ships contain each around 1854 kg of ozone depleting HCFC's H-phrase H420, adding up to a total amount of 7415 kg. The environmental price of this type of HCFC is € 102,- per kg²⁹. Assuming a 100% release gives an impact on the category "ozone depletion" that equals €750.000,-. For the large amount of asbestos no environmental price is available.

In general End of Life (EoL) ships can contain the following (hazardous) materials: diesel oil (24541 kg), polychlorinated biphenyl (PCB) from plastic and cables (3250 µg), asbestos (219 kg), antifouling paint (8217 kg) and glass wool (2500 kg). Ko and Gantner (Ko and Gantner 2016) constructed a methodology to calculate the local added value and the environmental impact of ship scrapping. Total local added value (minus the environmental impact) of breaking one ship is estimated to be €156.637,-. Only 2 impact categories were included. The amount of CO₂ emission in kg is estimated to be a factor 2.63 higher than the benefit in euro. The environmental price of a kg CO₂ is €0.0566,- (2015 price). For one ship the impact on climate change is equivalent to €23.000,-. The figure of €100.000,- for the 4 ships is added to the environmental footprint (figure 7). The Comparative Toxic Unit for humans was estimated to be a factor $2.24 \cdot 10^{-7}$ per euro benefit which was too small to be added to the environmental footprint.

²⁸ Information taken from court ruling.

²⁹ The price of €102,- per kg R-22 was extracted from the online Dutch tool available on <https://www.ce.nl/milieuprijzen> since the

environmental price for R-22 was not available in the Handbook with European prices (CE Delft 2018). The Dutch prices may deviate from the European.

4.4 End of Life Vehicles

Case description:

The case originates from inspection results of the Government of Lower Bavaria, Bavarian Police, German Federal Agency for Goods Transport (Transboundary shipment of waste No.3/4 on 30th January and 12th April 2019). The case is about several transports of End of Life Vehicles (ELV) from Austria to Nigeria, classified as “used goods”. The load is made up of several cars, some with additional loading. After inspection the materials are classified as hazardous and non-hazardous waste (export ban and notification procedure). The original classification as non-waste is questioned. At least part of the load is waste (bad packaging, no testing documents available). Environmental damage is expected through illegal disposal and burning of tons of this material.



Photos: Bavarian Police, German Federal Agency for Goods Transport

Hazard identification and characterization

ELV are considered a mixed waste. The typical composition of an ELV is given in table 4. ELVs, when not depolluted or treated, are classified as hazardous waste. Materials with potential negative environmental consequences in ELVs include: oil, coolant, fuels, brakes and other fluids; heavy metals including lead (Pb) mercury (Hg), cadmium (Cd) and chromium (CrVI). Each year between 20 and 55 million litres of hazardous non-fuel liquids are unaccounted for. Another category of potential environmental impact relates to resource loss from not maximising ELV reuse, material recycling and recovery (EC 2017) (GHK in association with BIO Intelligence Service 2006) (Basel Convention 2017).

Exposure and risk characterization

Illegal treatment of vehicles in non-authorised treatment facilities causes environmental

harm if hazardous liquids or other hazardous substances leak into the environment and causes

injury to the health of people handling such materials in an inadequate manner. Spilled or burned engine oil and unsafe FCHC (fluorochlorohydrocarbons) handling from air conditioners, unsafe handling of the acid from lead-acid batteries and unsafe treatment, e.g. burning of plastics from ELVs, also pose grave concerns. Other sources of environmental impact are landfilling of waste from shredders and vehicles abandoned in the environment.

Risk assessment and Life Cycle Impact Assessment

ELV consist of many different relative small amounts of hazardous materials. Although multiple studies are available, it was difficult to find usable figures. For this evaluation only two aspects were picked out.

First around 500-1500 gr of FCHC R-134a is expected to be present in cars (Behr Service Hella 2013-2014). R-134a has the following H-phrases (H280, H370 and H371) (ECHA Last updated 19/3/20):

- H280 *Contains gas under pressure; may explode if heated*
- H370 *Causes damage to organs*
- H371 *May cause damage to organs*

The environmental damage of a release of 1 kg is equivalent to €73.70,-³⁰.

Second the amount of lead containing components in one lead battery is around 7.5 kg (Zhang 2013) (WHO 2017) (GHK in association with BIO Intelligence Service 2006). Lead compounds have various H-phrases (ECHA last updated 20/02/20), like:

- H360 *May damage fertility of the unborn child*
- H302 *Harmful if swallowed*
- H373 *May cause damage to organs*

The exact phrases depend on the composition of the individual lead compounds, but there is

quite some overlap. The H-phrases for lead dioxide are given in case 4.7 *Export of hazardous WEEE*. During improper recycling processes of lead batteries the material is heated, leading to toxic lead fumes (WHO 2017). Literature indicates that 10% of the original amount of lead or 750 gram may be emitted as fume. The impact of a kg lead fume is estimated to be €5370, - (CE Delft 2018) . The total impact on human health of one battery will equivalent to €4500,-.

This export also consisted of some old computer screens, possibly CRT screens. In case 4.7 *export of hazardous WEEE* it is estimated that one CRT screen can contain 1 kg lead dioxide. However it is not expected that this material will be heated to recover the lead. If the material is crushed and landfilled the lead can leach into the soil. The impact of 1 kg lead is equivalent to €8, - in environmental damage (CE Delft 2018). Assuming the load consisted of 10 ELV with lead batteries, the impact in this case in the category human toxicity was estimated to be equivalent to €45.000,-.

Table 4: Composition of a typical ELV (GHK in association with BIO Intelligence Service 2006)

Material/Fraction	Kg per ton ³¹ of ELV (2015)
Ferrous metal	650
Nonferrous metal	90
Plastics and process polymers	120
Tyres	30
Glass	30
Batteries	13
Fluids	17
Textiles	10
Rubber	20
Other	20
Total	1000

³⁰ The price of €73.70,- per kg R-134a was extracted from the online Dutch tool available on <https://www.ce.nl/milieuprijzen> since the environmental price for R-134a was not available in the Handbook with

European prices (CE Delft 2018). The Dutch prices may deviate from the European.

³¹ One ton is around one vehicle.

4.5 Transboundary shipment of food waste

Case description:

The case originates from inspection results of the Government of Lower Bavaria, Bavarian Police, German Federal Agency for Goods Transport (Transboundary shipment of waste No.1 on 8th May 2019). The transport came from Italy with the Czech Republic as final destination. The waste is classified as Basel Convention Code B3010 and EC list of wastes code 19 12 04 with the description "plastic and rubber" and recovery operation R12. According to the contract the total amount is 24 ton. More shipments of this kind of waste were planned during 2019 (or already had taken place). After inspection the conclusion is that the waste should be classified as Basel Convention Code B3060 or EC list of wastes code 02 06 01 "Waste of candies and chewing gum". The recovery operation is unclear. There is possible environmental damage through illegal disposal of hundreds of tons of this material. There is financial advantage by saving incineration costs.



Photos: Bavarian Police, German Federal Agency for Goods Transport

Hazard identification and characterization

After inspection the material was classified as waste from candies and chewing gums. The photographs confirm the presence of sweets. The main constituents are expected to be sugars and other easily biodegradable non-hazardous materials.

Exposure and risk characterization

Large amounts of easily degradable materials can cause local environmental effects like oxygen depletion and leachates of nutrients causing fresh water eutrophication leading to land use or land transformation. According to the case description the amount of waste is probably hundreds of tons.

Risk assessment and Life Cycle Impact Assessment

In LCIA the environmental impact of food waste

covers all emissions from the different steps of the food supply chain. (Maih, et al. 2018) (Tonini, Albizzati and Astrup 2018) (Scherhauser, et al. 2018). The later in the supply chain a product is wasted the higher its environmental impact.

The global warming impact of avoidable food waste in general is quantified between 2000 and 3600 kg CO₂-equivalents per ton. The case information indicates there were of hundreds of tons. The impact of 200 ton is equivalent to €40.752, ⁻³² in global warming potential. Uncontrolled landfilling gives an extra 900 kg CO₂-equivalents per ton emission compared to more favourable composting processes (Kim and Kim 2010). The extra impact of 200 ton landfilled food waste is €10.000, -. The total figure for 200 ton food waste is €50.000,- in the category climate change.

³² 3600 kg CO₂ equivalents x 200 ton x an environmental price of €0.0566,- per kg

4.6 Transboundary shipment of mixed plastics

Case description:

The case originates from Inspection results of the Government of Lower Bavaria, Bavarian Police, German Federal Agency for Goods Transport (Transboundary shipment of waste No.2 on 28th March 2019). The shipment came from Italy with the Czech Republic as final destination. Shipment documents classified the waste as Basel Convention Code B 3010 and EC list of wastes code 19 12 04. Documents mentioned recovery operation R12 with the description "plastic and rubber". The amount of the individual load was 24.4 ton. After load inspection the material is classified as a mixture of different wastes. The classification of the waste and the recovery operation are questioned. It may be destined for final disposal. There is possible environmental damage through illegal disposal of tons of this material and incineration costs are saved.



Photos: Bavarian Police, German Federal Agency for Goods Transport

Hazard identification and characterization

The pictures indicate the waste is highly heterogeneous. Different materials are present. The photos show plastics, foam (polyether), polystyrene foam, insulation materials but also wood, paper and board. An assessment for this type of heterogeneous waste is not straightforward. Constructing a detailed characterization of the material is most of the times not feasible. In this example it is assumed the material is similar to what is classified in

literature a PSW (plastic solid waste) or municipal plastic waste (MPW). The following plastic resins could be present: polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET) and polyvinyl alcohol (PVC) (Antelava, et al. 2019). It is probably difficult to recycle due to the presence of contaminants.

Exposure and risk characterization

According to the case description the amount illegally disposed of is 24.4 tons. If landfilled

plastic solid waste requires large areas of land (Antelava, et al. 2019) (BIO Intelligence Service April 2011b). Landfilling can cause pollution problems like leaching of persistent organic pollutants (POP) that can contaminate groundwater aquifers and soil. Soil contamination may serve as breeding ground for pests and diseases (Antelava, et al. 2019). While degrading the plastic is fragmented into smaller pieces known as macro and micro plastics. These are hazardous because they can easily be ingested by (marine) fauna. The plastic can then work its way up the food chain and increase in concentration as larger animals feed on lower trophic levels (Milios, Davani and Yu 2018).

Risk assessment and Life Cycle Impact Assessment

The results are based on Life Cycle Impact Assessment studies that compared the impact

of different treatment methods of municipal solid waste (plastics, papers and a small amount of organics and textiles) with the impact of landfilling. By using fast pyrolysis as a treatment instead of landfilling the impact on the environment can be reduced with 4281 kg CO₂ equivalents per ton of municipal solid waste, 31.8 kg SO₂ equivalents in acidification potential and 132 kg PO₄ equivalents in eutrophication potential (Wang, Wang and Shahbazi 2015). For 24.4 ton this is equivalent to 4281 x24 ton x 0.0566 €/kg = €5800, - in the category global warming. The price of SO₂ equivalents is €11.50,- per kg. The impact of 31.8 kg is equivalent to €8777,- in the category acidification. The price of PO₄ equivalents is €1.86,- per kg. The impact in the category eutrophication is equivalent to €5892,- (CE Delft 2018). Total impact is estimated to be €20.000,-.

4.7 Export of hazardous WEEE

Case description:

The case originates from personal communication of H. McCann, Environment Agency for England. The interception of the shipment has taken place in 2009/10. Law enforcement officers from the Environment Agency (UK) intercepted a number of containers described as “used electronics” on their way to Nigeria. On opening the containers they saw broken electrical items such as cathode ray tube (CRT) TVs and R12 refrigerators. The prosecuting party used experts to prove the items were waste, that CRT was a hazardous substance and that R12 was a banned ozone depleting substance. The Correspondents’ Guidelines No1 on WEEE were used to support that the items were waste. Electricians were hired to demonstrate that the items did not work and were therefore likely to be WEEE (Waste Electrical and Electronic Equipment) rather than UEEE (Used Electrical and Electronic Equipment). The electricians tested for the presence of oil in the refrigerator compressors and the presence of R12 as refrigerant. Experts confirmed that the televisions did include a CRT screen. Laboratory tests revealed the chemical composition of the CRT screen and classified the CRT TV as a hazardous product. The jury agreed with the prosecutor’s assessment that the materials were hazardous and therefore banned from export to Nigeria.



Photo originates from the internet

Hazard identification and characterization

With respect to the refrigerators the critical hazardous substance is R-12, a chlorofluorocarbon with hazard phrase H420 *Harms public health and the environment by destroying ozone in the upper atmosphere*. A refrigerator can contain around 300 grams R-12 (ATN engineering BV 2015). As a small table sized refrigerator is 85x50x60 cm = around 0.25 m³, a container of 68 m³ (frequently used model) can hold around 275 refrigerators.

CRT monitors can contain different types and amounts of hazardous substances. For this example we focussed on the amount of lead. One screen can contain around 1 kg lead dioxide. It has multiple hazard phrases (ECHA last updated 28/02/2020):

- H360 *May damage fertility or the unborn child*
- H373 *May cause damage to organs*
- H410 *Very toxic to aquatic life with long lasting effects*
- H400 *Very toxic to aquatic life*
- H302 *Harmful if swallowed*
- H332 *Harmful if inhaled*

The size of one 18 inch screen is estimated to be (39.85 x 24.41 x 35 cm=) 0.034 m³. One 68 m³ container can hold around 2000 computer screens. The total amount of lead dioxide is estimated to be 2000 kg.

Exposure and risk characterization

Through improper recycling and/or handling the total amount of R-12 at some point will be released to the atmosphere.

With respect to the CRT screens estimates are more difficult. The screens are difficult to recycle (Ciftci and Cicek 2017) (Singh, Wang and Li 2016) and can have a different chemical compositions. The inner glass surface of the panel glass can be coated with different layers which consist of different types of heavy metals and hazardous substances. As a consequence for CRT screens the changes of ending up at undesirable places are large. The exposure depends on the further activities with the material. If disposed in landfills lead and other heavy metals will slowly infiltrate into soil and leach into the groundwater. Because they are biopersistent vegetation (including crops) can take up the metals and pass them on indirectly to animals and humans. If incinerated without precautionary measures toxic emissions will occur (Niu, et al. 2012).

Risk assessment and Life Cycle Impact Assessment

The total amount of ozone depleting substance R-12 present in one container will be around 82 kg. The environmental price for R-12 is € 726 per kg³³. The total impact in the category ozone depletion is equals € 60.000, - euro. The impact for landfilling one container crushed CRT screens is equivalent to € 16.000, - (2000 kg lead with a price of € 8,- per kg for soil emissions (CE Delft 2018)) in the impact category ecotoxicity.

³³ The price of € 726 /kg was extracted from the online Dutch tool available on <https://www.ce.nl/milieuprijzen> since the environmental price for this particular chlorofluorohydrocarbon was not available in

the Handbook with European prices (CE Delft 2018). The Dutch prices may deviate from the European.

5. CONCLUSIONS

Every risk assessment or life cycle impact assessment (LCIA) starts with detailed information about the amount of waste, its (chemical) composition and (hazardous) characteristics. In illegal waste trafficking the shipping documents can be used as a starting point. They hold information with respect to the identity of the waste (the waste codes), the amount of waste and the recovery or disposal operations. If information on the shipping documents is doubted, subsequent verification with mobile field equipment or sampling and (chemical) analysis can assist to obtain the necessary information.

Whereas a risk assessment describes the local impact of a specific incident a Life Cycle Impact Assessment aims to describe the overall impact of all activities. The methodologies overlap and combinations of both methodologies might have added value. In cases where actual risks exist and environmental damage has been caused a risk assessment seems more natural. In situations where the impact of improper recovery or disposal processes needs to be compared with regular ones a LCIA will be superior. In a Life Cycle Impact Assessment the environmental impact is quantified. Numerical scores make it possible to compare recovery or disposal operations on standardized aspects like climate change, ozone depletion and (eco)toxicity.

Although illegal waste shipments disrupt the desired life cycles of products they were not a part of regular Life Cycle Impact Assessments. The evaluation of 7 case studies demonstrate that during the standardisation processes needed for a LCIA relevant information with respect to actual risks and damage might get lost. The evaluation also shows that the exact recovery and/or disposal operations of illegal waste transports might be unknown. The case studies were used to create an environmental footprint for illegal waste transports (see figure 7). The expected emissions in the 16 predefined LCIA impact categories were scored. To facilitate the interpretation the impact was monetized. The impact for the individual transports varied between €4000,- and €1.2 million euro with an average of around €320.000,-. Lack of information and data make that this outcome should be considered as incomplete and probably largely underestimates the real impact of illegal waste trafficking. The evaluated cases also show that whereas the focus of the legislative framework seems to be on hazardous waste, the impact of illegal transports of non-hazardous waste is significant as well.

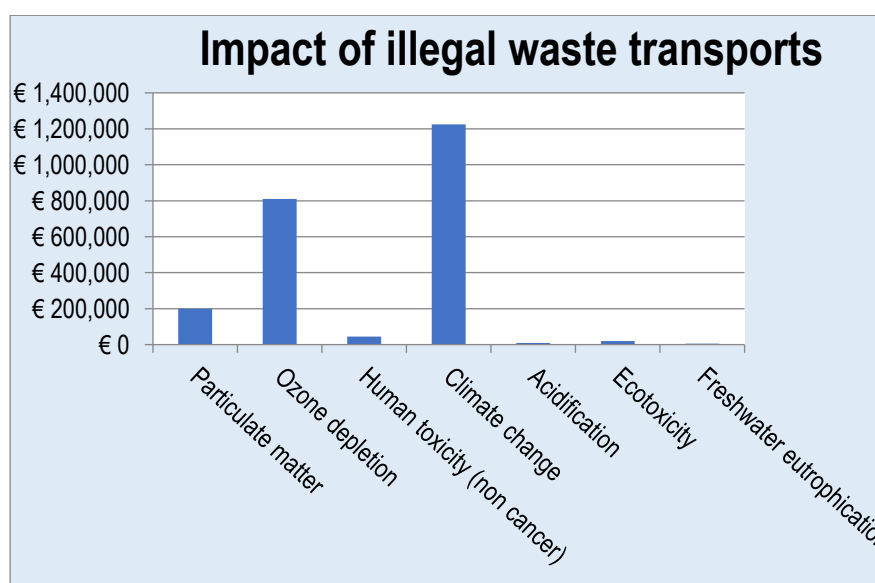


Figure 7: Environmental footprint for illegal waste transports

6. RESEARCH NEEDS AND INFORMATION GAPS

One of the major foreseen difficulties in the practical use of the designed framework is that for a proper risk assessment or Life Cycle Impact Assessment a lot of information needs to be collected during road inspections. Another issue is that although the methodology provides useful information it is still under development.

Some aspects to be named are:

- The EC has expressed the desire to create a circular economy and thus stimulates the creation of life cycle impact assessments for production processes. Illegal waste transports are however not an intrinsic part of those studies. It was quite difficult to find existing studies that did match the individual cases and to make estimates of the expected emissions caused by different recovery and disposal operations.
- Despite their apparent simplicity, the interpretation of LCIA profiles is not straightforward. Impact scores are expressed in complex units, and reflect environmental impacts in a way that does not correspond directly to perceptible problems or prevailing threats. Monetization as an alternative way of weighting the different impacts is not generally accepted and harmonised yet among the EU member states and internationally.
- Some well-known hazardous substances are not a part of LCIA or monetization processes yet. The impact of a substantial amount of asbestos in case study 4.3 *ship-breaking* for example was not taken into account.
- Different LCIA modelling techniques are available. Technology modelling principles and emission levels vary significantly between LCIA studies (Antelava, et al. 2019). This may limit the use of existing LCIA studies in actual forensic casework.
- In practice the construction of risk assessments and Life Cycle Impact Assessments in individual cases may be hampered due to limited resources and time, difficulties in handling the technical research options and handling the large amount of background information available.

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IMPORTANT SOURCES OF INFORMATION

<http://www.basel.int/>

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted on 22 March 1989 by the Conference of Plenipotentiaries in Basel, Switzerland, in response to a public outcry following the discovery, in the 1980s, in Africa and other parts of the developing world of deposits of toxic wastes imported from abroad. Their website holds information on illegal waste transports, legal matters, specific waste topics and technical guidelines.

<https://echa.europa.eu>

The European Chemicals Agency (ECHA) is the driving force among regulatory authorities in implementing the EU's ground-breaking chemicals legislation for the benefit of human health and the environment as well as for innovation and competitiveness. The ECHA databases contain information on correct allocation of hazard phrases to substances, toxicological information, safety aspects about handling and information about production processes.

<https://www.cen.eu>

CEN, the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 34 European countries. CEN is one of three European Standardization Organizations (together with CENELEC and ETSI) that have been officially recognized by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at European level.

<https://www.impel.eu>

The European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL) is an international non-profit association of the environmental authorities of the EU Member States, acceding and candidate countries of the European Union and EEA countries. The association is registered in Belgium and its legal seat is in Brussels, Belgium.

The core of the IMPEL activities concerns awareness raising, capacity building and exchange of information and experiences on implementation, enforcement and international enforcement collaboration as well as promoting and supporting the practicability and enforceability of European environmental legislation.

<https://www.interpol.int/Crimes/Environmental-crime>

The INTERPOL Pollution Enforcement team works with agencies in member countries to detect and disrupt pollution crimes and dismantle the groups behind them. Criminal networks involved in waste trafficking have also been found to be involved in fraud, money laundering, human, drug and firearms trafficking. INTERPOL-led operations, training and capacity building help law enforcement bring down criminal polluters.

<https://www.oecd.org/environment>

The Organisation for Economic Co-operation and Development (OECD) is an international organisation that works to build better policies for better lives. Together with governments, policy makers and citizens, OECD works on establishing international norms and finding evidence-based solutions to a range of social, economic and environmental challenges. From improving economic performance and creating jobs to fostering strong education and fighting international tax evasion, they provide a forum and knowledge hub for data and analysis, exchange of experiences, best-practice sharing, and advice on public policies and global standard-setting. On their web-site statistics

with respect to different types of wastes like generation of waste per capita and management operations are available.

<https://ec.europa.eu/eurostat>

Eurostat is the statistical office of the European Union situated in Luxembourg. Its mission is to provide high quality statistics for Europe. While fulfilling its mission, Eurostat promotes the following values: respect and trust, fostering excellence, promoting innovation, service orientation, and professional independence.

<https://eplca.jrc.ec.europa.eu/>

The European platform on life cycle assessment is the EU's knowledge base that responds to business and policy needs for social and environmental assessments of supply chains and end-of-life waste management, otherwise known as life cycle assessments. In 2013, the Communication from the Commission Building the Single Market for Green Products (COM/2013/196) established the Product- and Organisation- Environmental Footprint (PEF and OEF, or more generally EF). The common methods how to measure the life cycle environmental performances for PEF and OEF have been first defined in the EU Recommendation 2013/179/EU. The JRC has led the technical/scientific development.

ANNEX 1 Legislative framework

Article 191 of Treaty on the Functioning of the European Union 2008

This article sets out the origin of environmental protection in EU law.

Article 191

(ex Article 174 TEC)

1. Union policy on the environment shall contribute to pursuit of the following objectives:

- preserving, protecting and improving the quality of the environment,
- protecting human health,
- prudent and rational utilisation of natural resources,
- promoting measures at international level to deal with regional or worldwide environmental problems, and in particular combating climate change.

2. Union policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Union. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay.

In this context, harmonisation measures answering environmental protection requirements shall include, where appropriate, a safeguard clause allowing Member States to take provisional measures, for non-economic environmental reasons, subject to a procedure of inspection by the Union.

3. In preparing its policy on the environment, the Union shall take account of:

- available scientific and technical data,
- environmental conditions in the various regions of the Union,
- the potential benefits and costs of action or lack of action,
- the economic and social development of the Union as a whole and the balanced development of its regions.

4. Within their respective spheres of competence, the Union and the Member States shall cooperate with third countries and with the competent international organisations. The arrangements for Union cooperation may be the subject of agreements between the Union and the third parties concerned. The previous subparagraph shall be without prejudice to Member States' competence to negotiate in international bodies and to conclude international agreements.

Waste Framework Directive (WFD)

The WFD (2008/98/EC 19 November 2008) defines waste and sets out that it should be handled in such a way that it does not have a negative impact on the environment or human health. It contains an encouragement to apply the waste hierarchy and, in accordance with the polluter-pays principle, a requirement that the costs of disposing waste must be borne by the holder of the waste, by previous holders or by the producers of the product from which the waste came. It down measures to prevent or reduce the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use.

Strict conditions apply to the managing of hazardous waste, in particular:

- The obligation to provide evidence for the tracking of the waste according to the system put by the relevant Member State (Article 17 WFD); a mixing ban (Article 18 WFD, see for details the WFD Guidance).
- Specific labelling and packaging obligations (Article 19 WFD).

A hazardous waste is defined as a waste that displays one or more of the fifteen hazardous properties listed in Annex III to the WFD. In the context of waste classification, Article 7 WFD sets the basis for the List of Waste (see below) and its application.

European List of Waste (LoW)

The LoW provides further provisions for the assessment of hazardous properties and the classification of waste. It provides the list of wastes, categorised into chapters, sub-chapters and entries. The entries in the LoW can be categorised into 'absolute hazardous entries', 'absolute non-hazardous entries' and 'mirror entries'.

Commission Decision 2000/532/EC establishes the European List of Waste (LoW). The LoW is the key document for classification of waste. Full and compliant classification enables businesses and competent authorities for a decision in terms of the question whether the waste is hazardous or not. In this respect, the LoW recognises three types of entries:

- 'Absolute hazardous entries'.
- 'Absolute non-hazardous entries'.
- 'Mirror entries', where waste from the same source might under the LoW be allocated to a hazardous entry or to a non-hazardous entry depending on the specific case and on the composition of the waste.

The Waste Shipment Regulation

Regulation (EC) No 1013/2006 on shipments of waste ('Waste Shipment Regulation' or 'WSR') implements into EU law the provisions of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (Basel Convention 1989) and OECD Decision C(2001)107/Final. The WSR, which is directly applicable in all Member States, establishes the procedures, conditions and requirements to be fulfilled in the course of transboundary shipments of waste, including shipments between Member States. Article 34 of the WSR bans the exports of waste for disposal except to EFTA countries. Article 36 bans the export of hazardous and 6 other categories of wastes to non-OECD countries for recovery.

There are three control procedures for the shipment of waste, namely:

- The **general information requirements** of Article 18 which is normally applicable to shipments for **recovery** of wastes listed in Annex III ('green' listed wastes) or IIIA.
- The procedure of **prior written notification and consent** for any other type of shipment of wastes,
- A ban on the export of hazardous and other wastes (there are 7 categories in article 36) for recovery in non-OECD countries.

In the context of identification of waste for the purpose of correct procedure and documentation, the classification according to the lists contained in Annex III-IV of the WSR (the incorporated lists of international agreements) applies. These lists provide for a classification approach different to the one of the LoW.

However, classification according to WFD and LoW is also relevant in the context of the WSR, for instance as a criterion whether the waste may be exported for certain non-EU non-OECD countries (Article 36(1) WSR). The classification of waste in accordance with the entries listed in Annexes III-IV (i.e. Basel Convention and OECD codes) as well as the entries of the LoW (Part 2 of Annex V WSR) is to be indicated on the notification and movement document used in the framework of the notification procedure and in accordance with the instructions under point 25 of Annex IC. Likewise, the identification of waste is to be made on the Annex VII document in the case of shipments subject to the general information requirements of Article 18.

Regarding the case of shipments of waste subject to the procedure of prior written notification and consent, the codes to be used for the hazardous characteristics (H codes) and treatment operations (D and R codes) on the notification and movement documents (Annexes IA and IB) are those set out in Annexes III and IV to the Basel Convention, respectively.

Currently there is no listing for hazardous plastic waste in Annex VIII (the presumed hazardous listing) and, there is no listing for plastic wastes on Annex II (wastes requiring special consideration). There is only an entry (B3010) for Annex IX (presumed non-hazardous). A new listing (A3210) on Annex VIII (presumed to be a hazardous waste) has been created. Such wastes will be subject to the full regime of Basel control procedures and obligations and will be subject to the Basel Ban Amendment when it enters into force (2 countries still needed for global entry into force). The Ban Amendment prohibits all exports of hazardous wastes from developed countries to developing countries for any reason. The ban has been ratified and enters into force on 5th December 2019. It shall apply with effect from 1 January 2021.

The REACH regulation

The REACH regulation lays down the registration, evaluation, authorization and restriction of chemicals in the EU. Waste is not a substance, article or mixture within the meaning of REACH. Nevertheless, information generated in the framework of REACH may be relevant for waste classification.

Regulation (EC) 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals ('REACH') (16) entered into force in 2007. REACH is the general chemicals law at EU level, applying to substances (as such, in mixtures or in articles). The purpose of REACH is to ensure a high level of protection of human health and the environment, including the promotion of alternative methods for assessment of hazards of substances, as well as the free circulation of substances on the internal market while enhancing competitiveness and innovation. REACH defines and operates a number of processes with the overarching aim of ensuring the safe use of chemicals:

- registration of substances (requires the submission of information on the properties and uses of substances, subject to certain conditions, to the European Chemicals Agency ECHA);
- improved communication in the supply chain by means of extended Safety Data Sheets (eSDS);
- evaluation of substances by public authorities with the aim of providing certainty as regards the proper functioning of the registration process and to further clarify concern regarding certain substances;
- restriction of use of substances for which an unacceptable risk has been determined;
- authorisation applicable to certain substances of very high concern (SVHC) which can only be placed on the market and used subject to the granting of a specific and time-limited authorisation, subject to certain conditions.

No direct obligations apply under REACH for producers or holders of waste (although the waste stage has to be considered in the chemical safety report to be presented as part of the registration dossier for substances manufactured or imported in the EU in quantities above 10 t/y). However, information about chemical substances generated and communicated in the framework of REACH, particularly hazard information, and its subsequent use in classification according to CLP, is essential (see Annex 2) for the classification of waste. Note that test methods to be used for the purpose of REACH Regulation are indicated in Regulation (EC) 440/2008 ('Test Methods

Regulation'). Some test methods laid down in this regulation, or adaptations thereof, may be applied in the framework of waste classification.

The Classification, Labelling and Packaging Regulation

The CLP Regulation sets out criteria for the hazard classification of substances and mixtures. Waste is not considered as a substance, mixture or article under CLP. However, the hazardous properties applicable for waste are related to CLP criteria. Further, classification of substances under CLP may also be relevant for waste classification.

Regulation (EC) 1272/2008 on classification, labelling and packaging of substances and mixtures ('CLP Regulation') (17) adapts for the EU the UN international chemicals classification system (Globally Harmonised System — GHS). In this context, it sets out detailed criteria for assessing substances and determining their hazard classification. Similarly to REACH, Article 1(3) of the CLP Regulation lays down that waste is not considered a substance, mixture or article; consequently, obligations under CLP do not apply for producers or holders of waste. Although Annex III to the WFD is based on the CLP Regulation, it does not contain a full 'one to one' transposition of the criteria as laid down in CLP. Instead, in terms of the classification of waste, it should be noted that some of the HP criteria of Annex III to the WFD directly make reference to CLP hazard classes and categories and to hazard statements and associated criteria for classification. Many mirror entries specifically refer to 'hazardous substances'. The classification of substances is done according CLP whereas the presence of hazardous substances contained in waste has to be evaluated in line with Annex III to the WFD (see in detail 2.3.2 and Annex 3). Further, Table 3.1 of Part 3 of Annex VI to the CLP Regulation provides a set of official harmonised classifications of substances. Where such harmonised classification is available, it has to be used in the classification of waste (see for this particular aspect Annex 2, Section 2.1.1).

EU Ship recycling regulation

The Ship Recycling Regulation adopted in 2013 (EU No 1257/2013 sd) by the European Parliament and the Council of the European Union aims to reduce the negative impacts linked to the recycling of ships flying the flag of Member States of the Union. The Regulation lays down requirements that ships and recycling facilities have to fulfil in order to make sure that ship recycling takes place in an environmentally sound and safe manner.

The Regulation first prohibits or restricts the installation and use of hazardous materials (like asbestos or ozone-depleting substances) on board ships. The regulation applies from 31 December 2018³⁴.

New European ships and EU-flagged ships going for dismantling must also have on board an inventory of hazardous materials (IHM) verified by the relevant administration or authority and specifying the location and approximate quantities of those materials. This obligation will also apply from 31 December 2020 to all existing ships sailing under the flag of Member States of the Union as well as to ships flying the flag of a third country and calling at an EU port or anchorage. This will facilitate the recycling of vessels and reduce the presence of toxic materials on board ships. In November 2016, EMSA, the European Maritime Safety Agency, published a Best Practice Guidance on the Inventory of Hazardous Materials for practitioners on the field, ship owners and national authorities (EMSA 2016). EU Member States' port authorities will control ships to verify whether they have on board a ready-for-recycling certificate or a valid inventory of hazardous

³⁴ The Hong Kong International Convention for the safe and environmentally sound recycling of ships was adopted at a diplomatic conference held in Hong Kong China from 11 to 15 May 2009 but has not yet entered into force.

materials. EU flagged ships can only be recycled at ship breaking yards that are on the European List.

To ensure legal clarity and avoid administrative burden, EU-flagged ships covered by the Ship Recycling Regulation are excluded from the scope of the Waste Shipment Regulation (EC) 1013/2006.

Directive 2004/35/EC on Environmental Liability

Directive 2004/35/EC (Directive 2004\35\EC 21 April 2004) Environmental Liability Directive (ELD) establishes a framework to prevent and remedy environmental damage.

The ELD imposes administrative liability for damage to protected species and habitats, for contamination of land and for damage to surface waters, coastal waters, and groundwater. The ELD covers only significant environmental damage, defined as follows:

Damage to protected species and natural habitats is recoverable if it has “significant adverse effects on reaching or maintaining the favourable conservation status” (also defined in the Directive) of the habitats and species concerned. Damage to the waters is covered if it “adversely affects the ecological, chemical and/or quantitative status and/or ecological potential” of these waters. Land contamination can only be claimed for if it creates a significant risk to human health.

According to the Directive, where environmental damage has not yet occurred but there is an imminent threat of such damage occurring, the competent authority should either require the operator to take appropriate preventive measures or do so itself. Where environmental damage has occurred, the competent authority should either order the operator to take necessary restorative measures or take such measures itself (e.g., when the responsible party cannot be identified or fails to act) and recover their costs from the operator within five years of taking the remediation actions (Salanitro 2015) (OECD 2012).

Environmental Crime Directive 2008/99/EC

The directive lays down a list of environmental offences that must be considered criminal offences by all Member States, if committed intentionally or with serious negligence. The proposed directive does not create a list of new illegal acts. The existing law already provides for these prohibitions.

The Member States are required by the Directive to attach to these existing prohibitions criminal sanctions. Inciting, aiding and abetting the commission of these offences must be punishable as a criminal offence as well.

Member States must ensure that legal persons can be held liable for offences committed for their benefit. This responsibility can be of criminal or other nature.

Member States must ensure that the commission of the offences is subject to effective, proportionate and dissuasive criminal sanctions. For legal persons the sanctions can be of a non-criminal nature.

The directive only sets a minimum standard of environmental protection through criminal law to be adopted by the Member States. The Member States are free to maintain or introduce more stringent protective measures.

ANNEX 2 Link between Hazardous Properties and H-phrases

Hazardous property	Description	H-phrases CLP	Description
HP1	Explosive	H200 H201 H203 H204 H240 H241	Unstable explosives Explosive; mass explosion hazard Explosive; fire, blast or projection hazard Fire or projection hazard Heating may cause an explosion Heating may cause a fire or explosion
HP2	Oxidising	H270 H271 H272	May cause or intensify fire; oxidiser May cause fire or explosion; strong oxidiser May intensify fire; oxidiser
HP3	Flammable	H220 H221 H222 H223 H224 H225 H226 H228 H242 H250 H251 H252 H260 H261	Extremely flammable gas Flammable gas Extremely flammable aerosol Flammable aerosol Extremely flammable liquid and vapour Highly flammable liquid and vapour Flammable liquid and vapour Flammable solid Heating may cause a fire Catches fire spontaneously if exposed to air Self-heating: may catch fire Self-heating in large quantities; may catch fire In contact with water releases flammable gases which may ignite spontaneously In contact with water releases flammable gas
HP4	Irritant — skin irritation and eye damage	H314 H315 H318 H319	Causes severe skin burns and eye damage Causes skin irritation Causes serious eye damage Causes serious eye irritation
HP5	Specific Target Organ Toxicity (STOT)/Aspiration Toxicity	H335 H370 H371 H372	May cause respiratory irritation Causes damage to organs <or state all organs affected, if known> <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard> May cause damage to organs <or state all organs affected, if known> <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>

		H373	Causes damage to organs <or state all organs affected, if known> through prolonged or repeated exposure <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>
		H304	May cause damage to organs <or state all organs affected, if known> through prolonged or repeated exposure <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard> May be fatal if swallowed and enters airways
HP6	Acute toxicity	H300	Fatal if swallowed
		H301	Toxic if swallowed
		H302	Harmful if swallowed
		H310	Fatal in contact with skin
		H311	Toxic in contact with skin
		H312	Harmful in contact with skin
		H330	Harmful if inhaled
		H331	Toxic if inhaled
		H332	Harmful if inhaled
HP7	Carcinogenic	H350	May cause cancer <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>
		H351	Suspected of causing cancer <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>
HP8	Corrosive	H314	Causes severe skin burns and eye damage
HP9	Infectious	-	-
HP10	Toxic for reproduction	H360	May damage fertility or the unborn child <state specific effect if known > <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>
		H361	Suspected of damaging fertility or the unborn child <state specific effect if known> <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>
HP11	Mutagenic	H340	May cause genetic defects <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>
		H341	Suspected of causing genetic defects <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>
HP12	Release of an acute toxic gas	EUH029	Contact with water liberates toxic gas
		EUH031	Contact with acids liberates toxic gas
		EUH032	Contact with acids liberates very toxic gas
HP13	Sensitising	H317	May cause an allergic skin reaction
		H334	May cause allergy or asthma symptoms or breathing difficulties if inhaled
HP14	Ecotoxic	H400	Very toxic to aquatic life
		H410	Very toxic to aquatic life with long lasting effects
		H411	Toxic to aquatic life with long lasting effects

		H412 H413 H420	Harmful to aquatic life with long lasting effects May cause long lasting harmful effects to aquatic life Harms public health and the environment by destroying ozone in the upper atmosphere
HP15	Waste capable of exhibiting a hazardous property listed above not directly displayed by the original waste	EUH001 EUH019 EUH044 H205	Explosive when dry May form explosive peroxides Risk of explosion if heated under confinement May mass explode in fire