# Study in Relation to the Derogation for Hazardous Substances in Crates and Pallets (Final Report)

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# Contents

# Abbreviations

| | |
|---|---|
| CED | Cumulated energy demand |
| HM | Heavy metal |
| HWI | Hazardous waste incineration |
| LCA | Life-cycle analysis |
| MoE | Ministry of Environment (used in the context of Denmark) |
| MWI | Municipal waste incineration |
| PPWD | Packaging and Packaging Waste Directive |
| PE | Polyethylene |
| PRE | Plastics Recyclers Europe |
| RTP | Returnable transport packaging |
| SHWI | Solid hazardous waste incinerators |
| t | Tonnes |
| USA | United States of America |

# Glossary

"HM crates and pallets" = plastic crates and pallets containing a HM concentration **exceeding** the maximum concentration defined in the PPWD, which is currently 100 ppm.

"HM-low crates and pallets" = plastic crates and pallets containing a HM concentration **not exceeding** the maximum concentration defined in the PPWD, which is currently 100 ppm.

LCA = A cradle-to-grave analysis of environmental impacts.

# 1.0 Introduction

## 1.1 Background and Objectives of the Study

Under article 11 of Directive 94/62/EC (the Packaging and Packaging Waste Directive, PPWD) the concentration levels of heavy metals (HM) in packaging are currently limited to 100 ppm.

However, when the Directive was adopted in 1994, many of the plastic crates and plastic pallets that were on the EU market, especially those for bottles, contained heavy metals exceeding the limit concentration levels laid down in Article 11 of the PPWD (600 ppm by weight by 30/06/1998; 250 ppm by weight by 30/06/1999 and 100 ppm by weight by 30/06/2001). The HM were used as pigments and plastic stabilizers.

Studies showed that the negative environmental impact from extracting the HM from the plastic and treating the HM exceeded the environmental impact from allowing the HM crates and pallets to be reused and recycled under strict conditions.

Therefore, Commission Decision 1999/177/EC, prolonged by Decision 2009/292/EC[1] establishes the conditions for a derogation for plastic crates and plastic pallets in relation to the heavy metal concentration levels established in the PPWD to enable industry to reuse and recycle these plastic crates and plastic pallets into new crates and pallets with a maximum addition of 20 % virgin material in a closed-loop recycling process. This is intended to address the particular concern that open recycling may lead to cross-polluting other products. Recycling the plastic crates and pallets that are on the market and that contain heavy metals, avoids the need to use virgin raw materials as well as the need to landfill or incinerate waste from these plastic crates and pallets.

The ultimate objective is to gradually phase out from the EU market all plastic crates and pallets with a heavy metal concentration level exceeding the limit of 100 ppm set in Article 11(1) of the PPWD.

However, pallets and crates exhibit long operational lifetimes of typically 15 years and often longer. The original foreseen phasing out scheme according to the PPWD was therefore revisited.

Commission Decision 2009/292/EC outlines the intention to review the functioning of the system provided for in this Decision and the progress made in phasing out plastic crates and plastic pallets containing heavy metals after five years.

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[1] OJ L 79, 25.3.2009, p. 44

The objective of this study is to analyse different options to address the presence on the EU market of plastic crates and pallets with a heavy metal concentration level exceeding the limit of 100 ppm set in Article 11(1) of the PPWD, to assess available data and information, identify and address remaining needs with a view to assisting the Commission services in evaluating the policy options from an environmental, economic and social perspective. This study builds on a previous study on the issue carried out in 2008[2] (further referred to as the "BIO IS (2008)" study), whilst incorporating new input from Member State representatives and relevant stakeholders.

## 1.2 Methodology and Information Sources

The information gathering conducted for this review included national authorities who are obliged to monitor any systems that use heavy metal containing crates and pallets.

In addition, the consultants prepared questionnaires and interviewed identified European and national stakeholders and relevant experts. This included organisations such as the Plastic Recyclers Europe, the European Federation of Bottled Water and the Brewers of Europe as the main representative for companies using a multi-way packaging system for beer and mineral water.

According to the BIO IS (2008) study on heavy metal containing crates and pallets, Germany constitutes the largest market for heavy metal containing crates. Therefore interviews were held with the Cooperative of Mineral Water Producers – 'Genossenschaft Deutscher Brunnen' (GDB 2014), the Brewers Association – 'Brauer-Bund' (BB 2014) and the Association of Non-Alcoholic Beverages – 'Wirtschaftsvereinigung für Alkoholfreie Getränke' (WAFG 2014). In addition, the monitoring report for heavy metal containing crates by GVM (GVM 2014) was supplied by LAGA Thüringen.

Further information was obtained from a general literature review and as well as additional documents provided by stakeholders.

## 1.3 Policy Options Assessed

The aspects to be covered in this study should enable the Commission to decide on the future course of action. In addition to gathering information from Member States on their systems for returnable transport packaging (RTP), further information is gathered which is fed into an appraisal of the following options[3]:

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[2] BIO Intelligence Service (September 2008) Study To Analyse The Derogation Request On The Use Of Heavy Metals In Plastic Crates And Plastic Pallets, report for the European Commission DG Environment

[3] Landfilling of RTP waste was excluded as an option from this study because landfill is regarded as the least preferable management option and should be limited to the necessary minimum.

- **Business as usual:** Continuing the current exception leading to a very gradual phasing-out of heavy metals in plastic crates and pallets.
- **Option 1:** Recycling with extraction of heavy metals whereby the plastic matrix is conserved.
- **Option 2:** Other forms of recovery – transforming to oil/gas and HM being extracted and used for construction or other purposes, or landfilled.
- **Option 3:** Incineration, whereby HM remain in slags and ashes which are used for construction or other purposes, or landfilled.

For all options, basic questions relating to technical feasibility will be addressed, as well as investigations on the environmental, social and economic impacts.

The assessment of the technical feasibility needs to consider available technology, the possibility of treatment of extracted heavy metals, as well as possible constraints and incentives for investment in the further development of techniques and processes for the extraction of heavy metals from plastic crates and pallets and identification of workable incentives.

The assessment of the environmental impacts requires a special focus on extraction and treatment of heavy metals at the current state of technology, as well as the destinations of the heavy metals through thermal treatments.

The assessment of the social impacts requires a focus on heavy metal extraction with respect to the estimated work and budget to extract and treat them, as well as potential impacts relating to a shift from reusable to non-reusable packaging and real time needed and the economic loss to withdraw all HM crates and pallets from the EU market.

For all options the an estimate will be provided of the time necessary to reach a situation where all plastic crates and pallets on the market comply with the limit concentration value set by the PPWD.

For the following options in particular, some specific questions will be addressed, including:

- **Option 1:** To consider the physical and chemical potential for the detoxification of heavy metals in a polymer matrix, at the current state of technology.
- **Business as usual:** To assess the impact of the current derogation and to estimate the number and relative amount of crates and pallets exceeding the limit values compared to those not exceeding these values. The environmental impact of this policy needs to be considered in comparison to the alternatives. There is also a need to check that no heavy metals are released under the conditions of the recycling process and that the material remains in a closed and controlled loop.

## 1.4 Types of Packaging Affected

For the purposes of this report, the plastic crates and pallets can be separated in four major forms as identified in Table 1-1.

The investigation below focuses, in the main, on crates for beverage containers (typically refillable bottles) as, to date, this is where the major area of concern relating to heavy metal content has been according to the BIO IS (2008) study. Boxes for transport food and with food contact are not contaminated with heavy metals due to applicable EU legislation[4]. Some pallets are thought to contain heavy metals, but only limited information on HM concentration levels is available. Due to the greater size and higher value of these items they are more likely to be retained in controlled product loops.

4 Commission Directive 2002/72/EC of 6 August 2002 relating to plastic materials and articles intended to come into contact with foodstuffs, repealed and replaced by Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food. Commission Regulation (EC) No 282/2008 of 27 March 2008 on recycled plastic materials and articles intended to come into contact with foods and amending Regulation (EC) No 2023/2006

## Table 1-1: Common Types of Returnable Transport Packaging

| Type | Description | Example |
|---|---|---|
| **Beverage crates** | Containers used for refillable beverage / beer bottles |  |
| **Food / agricultural crates and boxes** | Boxes of various forms (crates or boxes) for agricultural products or other products which travel between producers and retailers. These containers may be in direct contact with food and are therefore without contaminants. Containers with food contact are also regulated by efsa (2002/72/EC; 282/2008/EC) |   |
| **Industrial crates / boxes** | Boxes of various forms (crates or boxes) for industrial purpose or other products which travel between producers and retailers |  |
| **Pallets** | Pallets from plastic are used to transport goods between companies |   |

*Sources: Pictures from David Benbennick, Babi Hijau, Nino Barbieri, Paul Craemer GbmH and Walther Faltsysteme GmbH via Wikimedia Commons, and BIO IS (2008) study* [2]

## 1.5 Heavy Metal Content of Affected Packaging

The heavy metals in plastic crates and pallets result from heavy metal pigments which were used as the colorants in the 1970s and the early 1980s. The main pigments are either cadmium containing pigments or lead-chromate containing pigments. Mercury containing pigments have rarely been used.

Both pigments are classified as very toxic and are no longer on the market.

No recent analysis of the concentration of heavy metals in plastic crates and pallets is known to have been performed. However, discussions with stakeholders consulted during this review indicated that due to closed-loop recycling processes the concentration of the heavy metal containing pigments will not have changed very much over time (GDB 2014). The heavy metal content in affected plastic crates and pallets is therefore thought to be very similar to the previous report, and is thus reproduced directly from the BIO IS (2008) study in Table 1-2.

### Table 1-2: Typical Heavy Metal Concentration in Affected RTP

| Heavy metal | Concentration (ppm) |
|---|---|
| **Mercury** | Very small |
| **Cadmium** | Up to 1400 ppm |
| **Lead** | Up to 1000ppm |
| **Chromium as chromate (Cr VI)** | Up to 400 ppm |

*Source: BIO IS (2008)*

# 2.0 Information from Member States

Decision 2009/292/EC obliges Member States not only to ensure the setting up of a system of inventory and record keeping and a method of regulatory and financial accountability, it also obliges Member States to include in the reports on the application of the PPWD to be submitted every three years to the Commission, a detailed report on the functioning of the system provided for in the Decision and on the progress made in phasing out plastic crates and pallets with a HM concentration level exceeding the maximum value of 100 ppm. However, it was identified at the outset of the project that in the mandatory Member States report on packaging covering the years 2010-2012, this information was not provided. This has impeded efforts to quantify crates and pallets, and those with a heavy metal concentration exceeding the PPWD limits.

Questions were addressed to Member State representatives on the Technical Adaptation Committee for packaging and packaging waste to provide a short description of the system of inventory and record keeping in the Member States, to advise on whether there are any known RTP systems in place where the HM concentrations exceed the PPWD limits, and to identify any efforts undertaken to phase out plastic crates and pallets exceeding the heavy metal limits.

Based on the information provided, the most common situation would appear to be as follows:

- Packaging legislation (including heavy metal concentration limits) is implemented in the Member States.
- In a large number of cases, the derogation for plastic crates and pallets has also been transposed.
- In only a limited number of cases are monitoring and reporting activities effective. There is typically very limited information available at the Member State level for the quantities of affected returnable transport packaging. In certain cases it is clear that obligations are imposed on packaging producers and holders to keep records, but this information has not been centralised and critiqued. In other cases although there is an obligation to report any packaging exceeding the PPWD HM limits, it cannot be determined whether the lack of knowledge of HM crates and pallets relates to a genuine absence of them from the national market, or merely a lack of reporting.

# 3.0 Quantification of Packaging with Heavy Metal Content

## 3.1 Overall European Situation

RTP is not a homogeneous market because the users of individual packaging units often come from different industrial sectors with different requirements of or specifications for the packaging. The information available is also very varied and therefore it is difficult to give an accurate quantification. While information is available and relatively accurate for the smaller retail crates, the situation for the larger industrial boxes and pallets is less clear.

The BIO IS (2008) study quantified the plastic crates and pallets in circulation as shown in Table 3-1.

## Table 3-1: Pool of Plastic Crates and Pallets in EU-25 in 2008

| Returnable Transport Packaging | Units (millions) |
|---|---|
| **Retail RTP** | |
| Beverage | 830-1500 |
| Agricultural | 300-400 |
| Supermarket | 170-220 |
| Bakery | 30-35 |
| Dairy | 30-35 |
| Non-food retail | 90-100 |
| **Retail sub-total** | **1450-2290** |
| **Industrial RTP** | |
| Postal | 100-110 |
| Horticultural | 90-110 |
| Automotive | 60 |
| Other industrial | 60 |
| **Industrial sub-total** | **310-340** |
| **RTP TOTAL (approximate)** | **1800-2600** |

*Source: BIO IS (2008)*

This study roughly estimates the total weight of RTPs as 4.1 million tonnes in total. The weight given for small RTP was approximately 2.7 million tonnes with an average weight of 1.5 kg. The large RTP was indicated to represent 1.4 million tonnes based on an average weight of 15 kg per unit (noting that small and large RTP exist in both retail and industrial sectors). It should, however, be noted that these estimate (units and weights) have a high degree of uncertainty.

Overall, the total quantity of plastics with heavy metals above 100ppm is estimated by BIO IS (2008) as 2.5 million tonnes, assuming 60% of the RTP units are affected. This may be considered an upper bound as the accuracy of the 60% figure is questionable, and other information suggests the heavy metal issue may be more relevant to beverage crates.  For beverage crates alone, the 2008 data estimated one third in total to be affected, hence around 0.7 million tonnes.

The European stakeholders confirm that no new data on RTP exists, and insufficient information was available to construct new data as part of this study. The very limited recent knowledge from Germany discussed in Section 3.2 suggests that the number of crates may have reduced by around 60 million between 2008 and 2012, though it is also discussed that this may not be reflected in a similar reduction in weight since lighter weight crates may have been replaced by heavier weight ones.

## 3.2 European Situation for Crates

The European Federation of Bottled Waters (EFBW) locate the problem of older, heavy metal containing crates in Belgium, the Netherlands, Germany and partly also in Austria (EFBW (2014)). For the breweries, the main market for returnable beer bottles (and hence a high demand for crates) exists in Germany, France, Italy and Spain. As EFBW and Brewers of Europe have not performed a new monitoring program since 2008, there is no new data available. Both the EFBW and the Brewers of Europe estimate that the fundamentals for the market have not changed and the data remains essentially the same as reported previously estimated by the BIO IS (2008) study.

### Table 3-2: Best Estimate of Beverage Crates (million units) in the EU

| Region | Crates (million units) | of which heavy metal containing (million units) | Source |
|---|---|---|---|
| **Europe – 2008** | 1500 | 500 | BIO IS (2008) |
| **Belgium – 2008** | 7 | 2 | BIO IS (2008) |
| **Germany - 2008** | 500 | 300 | BIO IS (2008) |
| | | | |
| **Germany - 2012** | 440 | 221 | GVM (2014) |
| **Europe – 2012** | 1440 | 421 | (inferred from above data) |

Table 3-2 shows the data from the BIO IS (2008) study, updated with new data from Germany generated in 2012, as reported in GVM (2014). The number of plastic beverage crates in Germany has significantly declined from 500 to currently 440 million units for all crates and from 300 million units to 221 million units for heavy metal containing crates today. This data is hampered by a general uncertainty in the measurement methodology according to the interviewed stakeholder [GDB (2014)]. The current data is modelled and derived from monitoring of changing stocks, not on the stocks itself. Additionally, a change in the market may explain part of the change; for instance lightweight old units replaced by heavier units; for example small crates for six bottles may be remanufactured for a 24 bottles unit. Consequently, it is thought that the number of crates has declined but the overall material is still the same amount [GDB (2014)].

The information provided by stakeholders identifies that crates that are damaged or unsuitable for reuse are separated at the refiller plant and grinded. The recyclates are remoulded to new crates with approximately 2 % additives (plasticisers and colour). Virgin material is not added as there is no technical need to do so. Remnants from gas filters etc. are gathered and moulded and grinded again. After this operation the grinded material can be added to the other recyclates.

The grinded recyclate is remoulded to new crates without either virgin material or new heavy metal pigments. Because of this closed-loop operation the concentration of heavy metals is constant. A dilution in HM-concentration in the stock can only occur if the stock of crates were to grow without any HM containing plastic being available, which has not been the case to date.

### Box 3.1: The German Monitoring Program

The five main stakeholders in Germany GDB, Brauer-Bund, WAFG, VDF and PETCYCLE commissioned the GVM with a report on the calculated return rate of heavy metal containing crates in Germany. The objective of the report is to prove a high return rate and thus bolster the claim of product loops which are in a closed and controlled chain.

Beside the data from our own research on the packaging market, crate producers and the stakeholders have also contributed data. An important part of the monitoring is contributed by "recrate", which – on behalf of the stakeholder – monitor:

- HM crates which are disposed or grinded for reuse.
- HM crates accepted by crate producers.
- New HM crates produced by crate producer.
- Exports of HM crates or grinded plastics thereof.

As well as providing market information, this report helps substantiate that the obligation for 90% of HM plastic crates are returned to manufacturers, as outlined below in Section 4.4.4.

### Box 3.2: The GDB system for mineral water

The German "Genossenschaft Deutscher Brunnen" (GDB) is a cooperative of mineral water producers which holds the license for a pool of crates (and bottles). This cooperative is quite old and started the operation of plastic crates in 1967. The crates in the pool are owned by the mineral water producers, which are normally SMEs. They can sell their crates (or the grinded recyclates) to other companies of the pool. There are three types of crates:

1) Yellow/brown crates, designed for sparkling water in glass bottles, are the oldest crates. These used cadmium and lead as pigments. In recent decades the demand for these crates are declining.
2) Blue crates are used for mineral water in PET bottles. These crates have been produced from the yellow crates remoulded with the addition of colours. Therefore these crates also contain heavy metals.
3) New lime-green crates are for used for natural mineral water. They have been produced from virgin materials without heavy metal containing pigments. The lime-green colours cannot be produced from crates with yellow colours (the older crates).

After years of decline the mineral water producers are experiencing a stable to slight growing market.

Market supervision shows that the crates travel four times a year with a life span of approximate 25 years on average. The overall number of reuse cycles for crates is therefore expected to be 100 times (this being only relevant for crates, bottles differ).

## 3.3 European Situation for Industrial Boxes and Pallets

The information on industrial boxes and pallets is limited and often features conflicting views. The share of boxes and pallets (in units) may be low in comparison to crates but the average specific weight of boxes and pallets may be significantly higher (up to 10 times) than the specific weight of crates. On the basis of weight, boxes and pallets may play an important role on the European market. Stakeholders indicate that the industrial boxes and pallets are generally owned by large companies and travel mostly within the company or between the company and pre-chain producers [PRE (2014)].

In general, PRE estimates that boxes and pallets for industrial use are a growing market. Heavy duty plastic pallets in industry are relatively new in comparison to wooden pallets. The production of these type of pallets started in the early 1990s and has shown a remarkable growth, which is estimated to be approximately 5% per year. Most of these pallets are produced from post-consumer plastic (PRE 2014). Given the relatively recent growth in this type of packaging, this material might be less affected by heavy metals as compared to bottle crates, which according to the BIO IS (2008) study *"are assumed to be at the heart of the heavy metal issue"*.

"Recrate", the organisation which monitors the German market for crates, has observed that 181 tonnes of heavy metal containing plastic material from crates were used for the production of plastic pallets in 2012: approximately 90,000 crates with an average weight of 2 kg were remoulded to 3,600 pallets, 50 kg each. On the basis of the existing stocks (over 300 million across Europe as indicated by the 2008 data in Table 3-1), this exchange is still relatively small.

# 4.0 Policy Options

This section presents a detailed discussion of the three alternate management options considered within this study, as well as considerations around the current derogation (which is considered as a business as usual option). The full environmental, social and economic analysis is presented separately in Section 5.0.

## 4.1 Option 1: Recycling with Extraction of Heavy Metals

### 4.1.1 Technology Review

In an extraction process the heavy metals are extracted from the plastic matrix in which the heavy metals are included as pigments. The plastic matrix has to be dissolved in a solvent (xylene or other organic solvents). The pigments are extracted to a water phase. The solvent is afterwards evaporated and the plastic is received from the plastic / solvent mixture.

No progress has been made since the BIO IS (2008)[2] report on those technologies previously identified:

1) The Eindhoven University of Technology process was previously developed but never put into operation beyond the laboratory scale.[2]
2) The BIO IS (2008) report mentions operations in Denmark and Italy *"that led to very poor results"* but does not give further details.[2] No additional information could be obtained as part of this review.
3) The Sea Way Refining operation operated a low capacity plant which was previously reported to have burned down.[2] The company has since decayed (Sea Way 2014).

In general the extraction of contaminants or heavy metals from a polymer matrix is an established route in technology (see FhG-IVV).[5] Besides the SEA WAY Refining operation this technology is today only applied to high-priced materials (see CreaSolv® Process[6]).

The FhG-IVV (Fraunhofer Institute for Process Engineering and Packaging) has developed several processes for the recycling of plastics via extraction. On a laboratory scale, the IVV has investigated heavy metal containing plastics (PE) and received good quality recyclates with a heavy metal content that is lower than 100 ppm (Mäurer 2014). So the process may have the potential to treat heavy metal containing RTP efficiently. A further development of this process to a pilot plant stage has not occurred because of missing funds. In the interview with the Plastic Recyclers of Europe, this technology route was indicated as too demanding from a technological point of view and too costly.

It can be concluded on the basis of this information that Option 1 is technologically feasible in principle, but that no capacity exists today. More scientific research is needed for developing a process to pilot plant level and further upscaling. As the developed technology is highly specific, a secure investment environment (demand for treatment) would be needed.

In this option the heavy metals of the HM crates and pallets will be extracted from the plastic matrix by a solvent. In a second extraction step the heavy metals will be transferred from the solvent to a water phase. The heavy metals are concentrated in the water phase as a salt. For further processing the water phase needs to get further concentrated, either via water evaporation or via chemical-physical treatment which will result in a heavy metal hydroxide. The metal content is estimated to be approximately 50 % (dry matter) which is normally far above the metal content asked for by recyclers. Taking into account the chemical analysis from Bio-IS (Bio 2008) the composition of heavy metals in crates and pallets consists not of a pure pigment (single metal) but a mixture of cadmium, lead and chromium. Lead and chromium recyclers do not accept

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[5] http://www.ivv.fraunhofer.de/de/geschaeftsfelder/kunststoff-rezyklate/hochwertiges-kunststoffrecycling.html.
[6] http://www.creacycle.de/de/der-prozess.html

waste/scrap with cadmium content of more than 300 g/t because pyro-metallurgical process steps are used that would lead to very high cadmium emissions. An alternative is the removal of cadmium first. This can be done by classical alkalified precipitation or in an electrochemical deposition of cadmium (Faron 2012). Vacuum distillation as it is performed by Accurec (Accurec 2015) for nickel-cadmium cells is also an option. However, some cadmium remains in the lead and chromium mixture. A similar or even combined chemical process (precipitation) may be used to recover lead and chromium. Only the remains of this process which cannot be used as secondary metals anymore would become waste. In the case the recovery of lead and chromium cannot take place at the installation the lead and chromium residue has to be send to a traditionally lead and chromium recycler. Whether recycling of lead and chromium is possible after cadmium recycling is performed is unknown but a discussion of potential applications is given in the subsequent subsection.

### 4.1.2 Potential Markets for Heavy Metals if Extracted

Considerations around how the HM containing water phase can be subsequently treated are as follows:

- The water phase, liquid or solidified, is accepted by a recycler. According to our knowledge lead and chromium recyclers have a very low tolerance for (land hence low concentration limit for) cadmium.
- This suggests that any external treatment would best be done by a cadmium recycler first, who would produce lead and chromium residues that could be sent to appropriate onward recyclers.
- Alternatively, further internal treatment could be undertaken to refine and extract the cadmium, with the other residues sent to a conventional recycler which accepts lead and chromium residues/waste with low cadmium content.
- Finally, internal treatment could be undertaken to produce of all three metals.

The main target of this procedure is to achieve marketable metals or metal salts as a commodity or product, thereby achieving a recycling rather than disposal solution for the metals entrained in crates and pallets.

Today, there is a functioning market, and a market price that can be achieved, for cadmium metal. As cadmium consumption continues to reduce in Europe, exports to India or China are likely to increase where nickel cadmium cells are still produced. It can be noted that a decade ago 85 % of the cadmium consumption in USA was used in nickel cadmium cells (Faron 2012). However, cadmium containing products such as nickel cadmium cells or pigments have largely been phased out in Europe (and USA). Additionally, new cadmium metals are produced in zinc metallurgy where cadmium is a minor-metal, the cadmium production as metal or salt cannot be avoided. Cadmium removal from zinc ore is essential in zinc production, otherwise the cadmium accompanying zinc would be dissipated in the environment (e.g. within zinc roofing, tyres etc.). Taking into account the phasing out of cadmium in the Western world and the nature of “forced” cadmium production as a minor-metal, the future of the cadmium metal market is uncertain.

If accepted, lead and chromium recyclers can be expected to use the lead and chromium waste as a secondary material (Dehoust 2015) to their metallurgical processes and produce lead or chromium metals. These metals have a more buoyant market. As opposed to cadmium, lead and chromium (despite their toxicity) are still essential metals for European industry, and are currently mostly imported as ores. For lead and chromium, recycling is a basic source of supply. The major lead application remains lead acid batteries, while chromium is mainly aligned with steel products.

### 4.1.3 Synopsis of Environmental Considerations for this Approach

Although deployment of such recycling extraction processes has not yet been achieved beyond the laboratory scale, the possible environmental impact of option 1 would be very positive. The polymer matrix of the treated HM crates and pallets are obtained and can be processed to new plastic crates and pallets. The energy demand of the option 1 itself is estimated to be approx. 23 MJ/kg including a remoulding step. The cumulated energy demand of virgin plastic is 76 MJ/kg. Taking into account the energy required for the process, the benefits are 53 MJ/kg or 120 % of the heating value of plastic (42MJ/kg).

The heavy metals in this extraction process are obtained in the water phase and afterwards are concentrated. The heavy metals are neither emitted via air or water, but instead may be recovered for secondary uses, and therefore the environmental impacts of the technology can be considered to relate to avoided extraction of primary materials, and avoided pollution where crates would otherwise be disposed through other means.

The energy benefits of heavy metal recycling in this context are very small. The heavy metals substitute ores which generally are attributed an energy demand of maximum 10 MJ/kg (ecoinvent 2015). This is much lower than the embodied energy in the plastic matrix (76 MJ/kg). Given the fact that the HM content is also a trace component, the energy benefits of recycling crates and pallets relate almost entirely to the plastic matrix, whereas the contribution of metal recycling is negligable, especially given the relative weights of plastic to HMs. In other words, the energy related environmental benefits of recycling HM crates and pallets are dominated by the energy benefits associated with the plastic itself.

With only minor energy related benefits attributable to the recycling of HMs, it may therefore be taken that the overall environmental benefits of recycling crates and pallets would be expected to be dominated by any avoidance of emission of HMs to the environment. A recycling approach where heavy metals are retained for reprocessing, therefore could offer environmental benefits compared to options where metals are released (such as in municipal waste incineration).

However, the technical practicalities of a recycling operation where both the plastic and the HM content are recycled is quite uncertain. We have identified as part of this study a laboratory scale technology which promises to recycle the plastic content, though the HM content would still be expected to be disposed (to deep storage or hazardous landfill etc.). As such, in the subsequent analysis for Option 1 where we consider the HM content is recycled (see Section 5.0), this will require material processing steps being brought together which have not been done within the current state of technology identified as part of this review.

## 4.2 Option 2: Transforming to Oil / Gas

### 4.2.1 Technology Review

As has been shown by (for instance) the BASF Company during the 1990s, plastic can be converted to liquid hydrocarbons though pyrolysis type processes. The plastic is heated to low temperatures (often in the range 300-500°C) in a concealed environment without air and decompose to light hydrocarbons (methane), coal and a fuel substitute.

There are numerous companies touting this technology, though the number that would accept plastic with a HM content is thought to be limited. In this process, plastic is heated to approximately 250°C to 300°C under pressure and the plastic converts into a gas, a gasoil fraction and a solid char (coal). The heavy metals end up in the char fraction, which is then disposed by hazardous waste incineration. One of the companies engaged in this technology and that is marketing the treatment of plastic streams informed that it hopes to enter into contracts for building such recovery plants (Nill(2014)); four plants in Italy, Hungary and Germany are undergoing the approval process from authorities. The capacities of the plants range from 5,000 t/year to 20,000 t/year. The input of 5,000 t plastic is split to 500 t waste (mineral waste attached to the plastic which cannot be converted), 830 t coal, 570 t gas for internal heating purpose and 3,100 t gasoil and kerosene. The plant is able to handle heavy metals (without mercury) which concentrate in the coal stream. The total process cost will strongly depend on the revenues from the gasoil/kerosene output.

It is therefore apparent that the technology exists to transform plastic to oil/gas. However, experience with heavy metal containing plastic is not currently available. Future research is necessary to establish the fate of the heavy metals in the plant.

If we assume that the plant can handle heavy metals in plastic the heavy metals will be concentrated in the coal stream which constitutes 18 % of the input stream. The heavy metal concentration is enriched in the coal stream by a factor of more than 5. However, the coal stream has to be incinerated in another facility, most likely in a hazardous waste incineration (HWI) plant due to the significant HM content. Co-combustion in a coal plant is rejected because the HM content is a factor of 1,000 greater than coal. An alternate option might be co-combustion in the already cadmium containing zinc pyrometallurgy process where cadmium is a by-product. However, information of possible restrictions of lead and chromium could not be obtained as part of this study.

### 4.2.2 Synopsis of Environmental Considerations for this Approach

The environmental impact of this option includes some advantages. With an input of net 4,500 t and after deduction of the coal and gas streams the process delivers an output of 3,100 t of oil which can be further used in energy production.

The environmental fate of the heavy metals is connected to the fate of the coal stream. If the coal stream is treated in hazardous waste incineration (HWI) the heavy metals will end up in the waste streams and safely disposed.

Environmental impacts are further considered alongside wider criteria considerations in Section 5.0.

## 4.3 Option 3: Incineration

Incineration of waste in Europe can take place in two different types of incineration plants.

Municipal waste incineration (MWI) is a commonly used technology for the destruction and energy recovery of municipal waste. The technology uses moving grates for feeding and as the firing system. As the grates need to be shielded from high temperature the grates depend on minerals which come with the waste. A single plastic feed to the grate would lead to such a temperature that it will destruct the grates. Because of this, plastic can only be used as by-feed. After the normally two-stage firing system the exhaust gas passes the boiler. As the boiler is the most expensive part it defines the overall capacity. After dust precipitation an abatement system using caustic or lime cleans the gases from acidic gases like hydrogen chloride or sulphurous acid. Additionally a charcoal filter is often used alone or in combination with lime and a bag filter to remove heavy metals and other contaminants.

Hazardous waste incineration (HWI) is used to treat waste with dangerous properties or a high content of toxic substances. This technology differs notably by having a much higher capacity in the abatement system, which therefore reduces the risk of pollution. Solid hazardous waste incineration normally uses a kiln as the primary combustion chamber. Kilns are far more robust than grates. After dust precipitation an abatement system similar to the system in MWI follows. The difference is that HWI utilise a wet/caustic adsorption while MWI employ a dry/lime adsorption system. The abatement systems in HWI are designed to mitigate far higher concentrations of dust, heavy metals and other contaminants because, as opposed to MWI which deal with relatively homogeneous municipal waste, HWI is confronted with very high peaks of pollutants.

The applicability of treating HM crates and pallets in either type of incineration, together with discussions on the environmental considerations, is considered in the subsections below. The environmental impacts are further considered alongside wider criteria considerations in Section 5.0.

### 4.3.1 Municipal Waste Incineration

As incineration plants are designed to incinerate mixed municipal waste, the incineration of plastic crates faces two difficulties:

1) Plastic crates have a heating value (40 MJ/kg) that is four times higher than typical mixed waste. The municipal incineration plant normally uses municipal waste (10 MJ/kg) and the input is determined by the caloric value because of the

boiler. Therefore the input of crates is limited and the costs may be defined by the thermal load.

2) Plastic crates or pallets have no minerals (beyond the heavy metals) which would shield the grate from higher temperatures resulting from the combustion. Consequently, plastic crates are normally unfit for single incineration. Additionally the heavy metals cannot bind to the ash. Plastic could only be expected to serve as by-feed.

Transfer coefficients for cadmium, lead and chromium are shown in the next table, which has data taken from Reimann (2002) and UBA (2002). The data shows that cadmium evaporates to the raw gas while lead and chromium mostly stay in the bottom ash. 25 % of the cadmium of the original waste remains in the bottom ash while 75 % of cadmium goes together with the dust (or as a part from it) to the raw gas and ends up in the fly ash.

### Table 4-1: Transfer Rates of heavy metals in MWI

| Transfer of heavy metals from waste to raw gas | | |
|---|---|---|
| **(%)** | Reimann | UBA-Wien |
| **Cadmium** | 81 | 75 |
| **Lead** | 36 | 8 |
| **Chromium** | 13 | 10 |

The data for transfer coefficients and heavy metal concentration in bottom ash and fly ash vary depending not only on the cadmium concentration but also on the mineral content. A critical analysis of cadmium concentration in municipal waste by Alwast (2010) shows that sources are mostly attributed to nickel-cadmium cells and electronic waste. Significantly lower quantities of cadmium are found in other household goods. This uneven distribution of cadmium makes clear that standard analysis of waste might have problems to capture cadmium. Additionally the behaviour of cadmium during incineration in, e.g. in Ni-Cd-cells which is not combustible alone differs largely from cadmium incorporated into plastic which is readily combustible. The transfer of cadmium to bottom ash, fly ash or gaseous emission derived from normal operation in a MWI therefore has to be considered with care.

For the purposes of our example, the UBA (2002) data are provided below in Table 5-2, including the corresponding concentration of bottom ash (250 kg/tonne) and fly ash (15kg/tonne).

### Table 4-2: Heavy metal content in bottom ash and fly ash (average, mg/kg)

| Heavy metal | Bottom ash | Fly ash |
|---|---|---|
| **Cadmium** | 10 | 500 |
| **Chromium** | 350 | 650 |
| **Lead** | 2200 | 3000 |

The transfer of heavy metals in incineration plants depends largely on their vapour pressure. As the vapour pressure for the metals increases from chromium to lead to cadmium, the transfer of cadmium from waste to raw gas and therefore to fly ash and also air emissions is higher. In contrast, chromium has a low vapour pressure and thus concentrates in the bottom ash. While there is a higher transfer of cadmium to the gas phase, approximately 20 % of the cadmium still remains in the bottom ash as the weight of bottom ash is 16-times higher than the fly ash.

In the next table the transfer of cadmium is detailed. Nearly 80 % of the cadmium is transferred to the raw gas of which 99.9 % is abated. With "normal" cadmium concentration in waste of 20 g/t (i.e. 20 ppm) the cadmium concentration at the stack is calculated to 0.0033 mg/Nm³. If we take the HM plastic with a maximum concentration of 1300 g/t the resulting emission concentration would amount to 0.054 mg/Nm³. This emission level exceeds the limit value of 0.05 mg/Nm³.

### Table 4-3: Transfer Steps for Cadmium from Waste to Clean Gas

| Transfer steps | Transfer coefficient | Amount (indexed 100% for waste) |
|---|---|---|
| **Waste** | | 100 |
| **Waste -> raw gas** | 81 % | 19 |
| **Raw gas -> clean gas** | 99.9 % | 0.019 |
| **Clean gas concentration for 20 g Cd/t in waste** | | 0.0033 mg/Nm³ |
| **Clean gas concentration at 1300 g Cd/t in waste and after correction of 4-times higher exhaust gas volume** | | 0.054 mg/Nm³ |

*Source: Reimann (2002)*

For the disposal of heavy metals in HM crates and pallets in MWI, at best the HM crates and pallets can only be used as by-feed. Normal waste is needed to dilute the high cadmium content for the bottom ash to reduce cadmium concentration so that air emission limits can be complied with, and also so that the ash can be used in a recovery operation as explained below.

Typically, 1 tonne of municipal waste has a cadmium content of 10 g, of which 20 % (2 g) would end up in 250 kg bottom ash (= 10 mg/kg). If combusting 1 tonne of crates with 1000 g cadmium, 250 g would end up in the bottom ash. As such, for every 1 tonne of crates, 100 tonnes of municipal waste would be needed to "dilute" the cadmium concentration to 20 mg/kg. This would also require very careful mixing of crates with municipal waste, which might present its own operational challenges.

For cadmium the data shows that a potential high input of cadmium from crates needs a dilution factor of 100 (i.e. 100 tonnes of municipal waste is needed for 1 tonne of crates) so that the average concentration of cadmium in the bottom ash will only double. Given that the tonnage of crates and pallets exceeding the 100ppm limit is thought to be in the range 0.7 – 2.4 million tonnes, the necessary amount of municipal waste requiring co-

combustion may need to be up to 240 million tonnes. The capacity to achieve this is limited when taking into account that across the entire EU28 about 58 million tonnes of municipal waste were incinerated in 2012 (Eurostat data).

MWI plant use the energy from waste to supply either district heat or electricity. For an average MWI (400MPa, air-cooling) facility, the electricity delivered is estimated at 18 %, or 50 % of primary energy (cumulated energy demand).

Concerning financial implications, the assessment should consider the 'costs' of incineration and not 'gate fees' paid for incinerating waste. The gate fee or market price by a number of factors such as local competition, amount of unutilised capacity, desired feedstock mixes, approach to risk management through long term contracting of tonnage etc. The cost for the incineration of crates depends on how the costs are calculated:

1. By weight: a typical cost of incineration might be 125€/t.[7]
2. By caloric input: As MWI is limited by the caloric input and the heat from municipal waste is approximately 10 MJ/kg and from crates is 40 MJ/t, the cost will be four times higher, 500€/t.

### 4.3.2 Hazardous Waste Incineration (HWI)

An alternative to MWI is hazardous waste incineration (HWI). HWI has the following specific advantages for treatment of HM crates and pallets:

1. Advanced exhaust gas cleaning system;
2. Various feeding systems: solid, liquid, barrels;
3. Instead of bottom ash most HWI produces slags due to higher temperatures which physically bind the heavy metals.
4. HWI slags and filter ashes are disposed in hazardous landfills or underground storage facilities;

Because of the higher temperature employed, the amount of heavy metals transferred to the raw gas is significantly higher. The abatement system of HWI has a larger absorption capacity and can handle higher concentration in the raw gas more efficiently. Bottom ashes as well as fly ashes are normally disposed in special landfills.

The energy recovery of HWI is lower because of the design and the need of auxiliary firing. While the HWI is normally generating steam and produce electricity the HWI often need gas or oil in downtimes to keep the temperature of 1200°C. In our case the energy recovery is estimated to be 20 % primary energy (or around 7% net energy efficiency as

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[7] Eunomia (2014) *Development of a Modelling Tool on Waste Generation and Management – Appendix 5: Financial Modelling,* Report for the European Commission, http://ec.europa.eu/environment/waste/pdf/waste-generation-management-model.zip

exported electricity). As such, the environmental advantage of the energy recovery is lower than for MWI, though HWI does have a greater ability to contain the HMs.

The capacity of HWI plants is divided in liquid-only and solid hazardous waste incineration plants. According to one source the total available capacity of solid hazardous waste incinerators (SHWI) is estimated to 0.55 million tonnes per year [Tillmann (2012)]. Taking into account the rough estimate of 2.5 million tonnes of heavy metal containing RTP calculated by BIO IS (2008), the capacity of SHWI in Europe would be blocked for nearly 5 years for treating heavy metal containing RTP alone.

The costs for treatment in HWI strongly depend on the head balance and capacity balance (solid/liquid). Mr Hilche [GDB (2014)] estimates the cost of HWI at 4 €/crate.

## 4.4 Business as Usual: Continuing the Current Exemption to allow Recycling of Crates and Pallets with Heavy Metal Content

### 4.4.1 Dilution of Heavy Metal Concentration in Crates Over Time

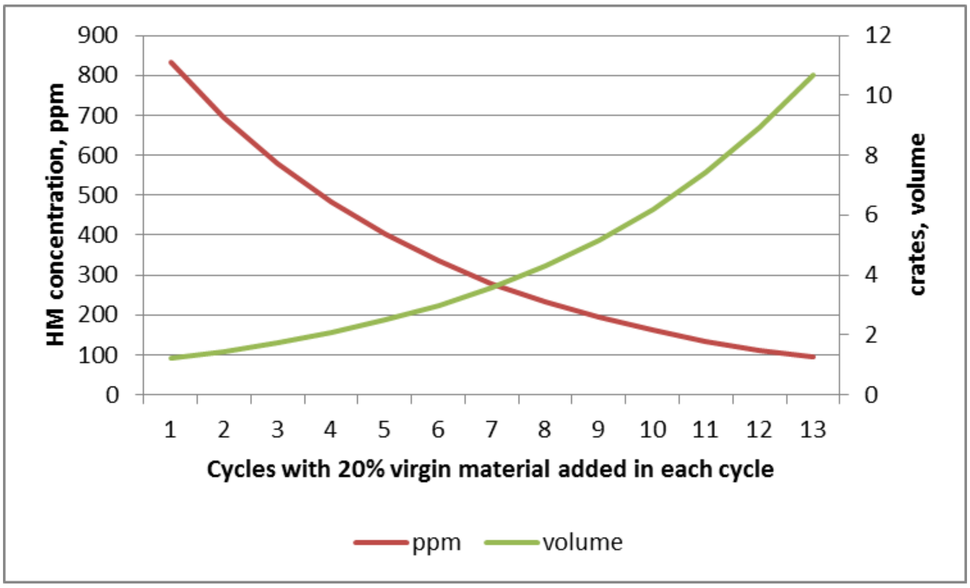
One way to decrease the concentration of heavy metals in crates is an ongoing dilution with virgin plastic material during the remoulding process. Interviewed stakeholders PRE (2014) and GVM (2014) state that no virgin material is added during the remoulding process (according to the requirements laid down in the law). In principle, a "dilution" may take place if there is a growing demand for "old-style" crates. These crates would be produced from virgin material and, if remoulded, may enter the contaminated stream and dilute the existing crates. But the existing stock of contaminated crates serves a declining market over the last two decades. So for the fraction of crates which already include heavy metals, **no dilution of the heavy metal concentration takes place today**.

The crates for a "new" market with new designs and new colours are – according to stakeholders PRE (2014) and GDB (2014) – manufactured from virgin material without any heavy metals.

The share of crates containing heavy metals above the maximum limit and crates below this limit (and even without any heavy metals) is changing because of the change in market share. Over the last decade this shift is estimated to be approximately 2 percentage points [GDB (2014), BB (2014)]. The GVM estimate a decline of market share of heavy metal containing crates from 52.7 % in 2010 to 51.4 % in 2012 [GVM (2014)], constituting a yearly decrease of 0.5-0.7 %. The explanation is a distribution of the grinded material to other users in Germany (pallets) or exports and partly losses.

Figure 4.1 shows the potential development if old, HM crates and pallets is mixed with 20 % of virgin plastics when the crates are remoulded. It shows the resultant development of the heavy metal concentration (starting point 1000ppm) and the amount of crates produced (starting point: 1) during remoulding cycles.

### Figure 4.1: Development of HM Concentration and Volume After Each Cycle




In the first cycle it is assumed that 20 % of virgin material is added[8]. This results in 1.2 crates with an average HM concentration of 833ppm. In the next cycle the volume increases to 1.44 crates with 694ppm. After the 13th cycle, the volume is 10.7 crates and the concentration is 93.5ppm, the first cycle with HM concentration below the 100ppm limit.

The average reuse time for crates is estimated to be 10 years (large breweries) to 25 years (mineral water, SME). If 13 cycles are necessary, the total time is calculated as 130 to 325 years.

Reducing the assumed starting heavy metal concentration to 400ppm saves 5 cycles, but it would still take a further 8 cycles to achieve the 100ppm limit.

Beyond the fact that the plastic structure decays over time, the volume produced by adding virgin material is very high. This procedure needs a growing market in an economic sector which is already stagnating.

Overall it appears that a dilution of heavy metal concentration in existing, heavy metal containing crates is not currently thought to be taking place. A dilution of heavy metals

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8 It should be noted, however, that stakeholders PRE (2014) and GDB (2014) made clear that they do not use virgin materials as the addition of virgin plastic is not technically necessary and that their new HM crates made from recycled ones will consist of 98% recyclates plus 2% additives (colours, plasticisers).

would only take place if the crates serve a growing market or via withdrawal and disposal.

Losses in the scheme are thought to be minimal. Some losses do occur during the grinding and manufacturing process as fine material or dust. The dust is retained in the exhaust gas filter. The collected dust is remoulded and serves as an input to grinding. Other potential losses might be the disposal of broken crates by households, but in the German system where households reclaim their deposit for broken crates, the losses are said to be minimal [GDB (2014)].

### 4.4.2 Amount of Crates and Pallets with a Heavy Metal Concentration Exceeding Limit Value

As discussed above in Section 3.0, there is no new European data beyond the GVM estimates, which only refer to crates. The GVM estimates identified in Table 3-2 above suggest a reduction in the number of HM crates in Germany from 300 to 221 million units, and an overall reduction in the total number of crates from 500 to 440 million. For other countries or Europe we have had to rely on the previous 2008 data obtained by BIO IS (2008).

It should be noted that the reduction refers only to the number of crates. In practise the weight of a crate can vary between 1.5 kg for a light 6-bottle tray and 4.5 kg for a 24-bottle crate. The two stakeholders (GDB, BB) explain the reduction in units by a change of type of crates on the market. Both argue that the amount of HM-laden material included has not changed.

The interviewed stakeholders [PRE (2014), BB (2014)] confirm that disposal (or recovery) does not take place as the old, heavy metal containing plastic material still holds a market value of approximately 500 to 800 €/tonne.

### 4.4.3 Synopsis of Environmental Considerations for this Approach

The environmental impacts in maintaining the exception compared to the use of new heavy metal free plastic material may focus on two indicators:

- Cumulated Energy Demand (CED, also called primary energy demand) for both processes including an energy benefit from disposal;
- Environmental impact of the treatment or the use of the extracted heavy metals.

The cumulated energy demand (CED) adds up all energy inputs which are needed to manufacture a product from the extraction of fuels to the manufacturing inputs. For the product (grinded plastic as input for moulding) the CED for old plastic is calculated as zero. For virgin plastic the CED is calculated to be 72 MJ/kg or 181 % of the heating value of plastic (ecoinvent[9]). If new material is used, the old material is disposed. We assume a

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[9] LCA database: www.ecoinvent.ch; version 2.1

municipal waste incineration plant with an energy production of approximately 15 % electricity in relation to the heating value. Overall the disposal in incineration with energy recovery will lead to a CED-benefit of approximately 50% of the heating value. In comparison the new plastic options will have an additional demand of 131 % of the heating value.

As the BIO IS (2008) study documented, heavy metals are included in the plastic matrix. Tests with eluate from heavy metal containing plastic show that the concentrations of heavy metal at the current concentration levels would have negligible health and environmental impacts and pose no risk to humans or the environment. Stakeholders GDB (2014) and BB (2014) claim that this risk assessment still holds. When compared to an incineration approach, in this case the heavy metals are relocated in the environment through ashes and to some degree though gaseous emissions.

Taking a life cycle analysis (LCA) view on the comparison of options, the boundary conditions must be the same between options. Consequently, because the business as usual option keeps crates in circulation, the environmental considerations for the alternate options must account for the manufacture of new HM-low crates and pallets to replace those taken off the market.

If we look at services, replacing the HM crates and pallets by crates and pallets not exceeding the maximum concentration level would mean a premature end of possible services for the old, heavy metal containing crates. As the new HM-low crates do not bring advantages for additional services, the overall CED is more positive for keeping the old HM crates and pallets on the market.

Another possible environmental impact in the recycling process of heavy metal containing crates and pallets are emissions during the grinding process as small particles or dust emissions which may be harmful to workers and, if released, to the general environment. As pointed out by the BIO IS (2008) study and confirmed by stakeholders (PRE (2014)), possible dust emissions are contained by bag houses or exhaust air filtering, are then collected and remoulded in a special process and fed into the original grinding process again.

For these reasons, the environmental appraisal given in Section 5.0 shows the most favourable outcome for the business as usual option.

### 4.4.4 Check of a Closed and Controlled Loop

A necessary condition for the derogation is that the HM crates and pallets are manufactured or repaired in a controlled recycling process with the following characteristics:

1. HM crates and pallets can only be used in a closed-loop and monitored recycling process.
2. The material for recycling shall only originate from other plastic crates and plastic pallets.

3. Introduction of other material should be limited to the minimum technically necessary and shall not exceed 20% by weight.
4. Intentional introduction of HM is not allowed (only incidental presence is allowed).
5. Exceeding the maximum concentration limit of the PPWD shall only be the result of the use of material containing HM in the recycling process.
6. HM crates and pallets shall be identified in a permanent and visible way.
7. There should be a minimum return rate of 90% to the manufacturer, the packer or the filler of the dispatched HM plastic crates and pallets

It has not been possible to confirm that all the above conditions are fulfilled in all MS as part of this review. However, from the information received, the following general observations can be made:

1. As detailed in chapter 4 the HM crates are handled in a closed loop system.
2. Stakeholders explained that they are using only recyclates from HM crates if remoulding crates to new HM crates (GDB 2014, BB 2014) (reported in Section 3.0).
3. According to stakeholders, no virgin material [except colours] are added (reported in Section 3.0).
4. No new HM are added (GDB 2014, BB 2014).
5. HM in remoulded crates are only the result of using recyclates from HM crates (see Section 3.0).
6. New HM crates are stamped to identify the plastic and its contaminants. Examples of such stamps are shown in BIO IS (2008).
7. Based on the BIO IS (2008) study and stakeholder input, it is assumed that the HM crates and pallets in circulation are indeed returned and not lost. This is thought to be the case due to the established handling logistics, the limited application of crates other than for their intended function, and because of deposits which are typically redeemable on crates in circulation even in the case that they are broken.

   This is supported by the information from the monitoring report from GVM commissioned by the German crate owners [GVM (2014)]. This report calculates a specific return rate of approximately 90 % for crates (i.e. for every 10 crates returned, 9 are redistributed once again).

   From the GVM report and the interview with RECRATE [RECRATE (2014)] (which monitors the transfer of grinded material) it is thought that the remaining 10% of heavy metal containing material goes to a mix of contained sources including grinding and adding to stocks, remanufacture into new crates, sold to other crate or pallet manufactures or exported. It is quite possible that exports are to crate or pallet manufacturers abroad, but this is not known at this time.

Even in the case where crates are lost in circulation, it would be expected that the HM-containing plastic would go in small amounts to MWI or to landfill in mixed waste streams, and is less likely to re-enter recycling processes.

As the monitoring only covers Germany and is only based on crates, future reports should also cover heavy metal containing RTP in Germany.

From these general observations, and specific information retuned by various member states, it would appear that there is conformity with the closed and controlled loop requirements.

# 5.0 Analysis of Impacts

For the analysis of impacts for the different options, we focus on the following impacts:

1. Environmental impacts.
2. Technical feasibility.
3. Available capacity.
4. Costs.
5. Social impacts.

All options are considered against the "further derogation / business-as-usual" case.

## 5.1 Environmental Impacts

For the environmental impacts, the following indicators have been considered:

**Table 5-1: Environmental Indicators Considered**

| Indicator | Explanation |
|---|---|
| **Energy Recovery** | The energy recovery is calculated as cumulated energy demand (CED) or primary energy and shown as a percentage of the heating value of plastic material. For option 1 the CED of virgin material is added because the material is still available. |
| **Concentration of heavy metal** | This indicator shows the concentration of heavy metals in a sealed environment; filter dust which is landfilled in mono landfills or underground storage. |
| **Distribution of heavy metals** | Indication of the distribution of heavy metals via ashes and emissions and possibly dissipates in the environment. |

**Table 5-2: Environmental Effects**

| | **Business as usual:** Further derogation | **Option 1:** Extraction | **Option 2:** Plastic-to-oil | **Option 3:** MWI | **Option 3:** HWI |
|---|---|---|---|---|---|
| **Energy recovery (primary energy in % of crate heating value)** | 181 | 120 | 70 | 50 | 0-25 |
| **Concentration of heavy metal** | no | extraction liquor | coal | ash + fly ash | slag + fly ash |
| **Distribution (heavy metals)** | HMs remain in plastic | no, HM recovered | no if coal sent to HWI | possible yes | no |

Energy conservation is calculated as the Cumulative Energy Demand (CED) and is one of the main environmental indicators. The existing system (the further derogation option) keeps the heating value plus the energy needed for the production process itself to produce polyethylene. In option 1 (Extraction) the process not only conserves the heating value but also part of the process energy of the plastic production. The two other options can only make use of the heating value of the plastic. Option 2 (Plastic–to-oil) has additional losses (coal, gas) which reduce the efficiency. Incineration produces only heat or electricity.

The heavy metals should be contained and concentrated. The extraction and plastic-to-oil process seem favourable. The heavy metals are concentrated in either liquor (extraction) or in the coal. The heavy metals are best contained if the residues go to a hazardous waste landfill or underground storage. The concentration factor for MWI is low and heavy metals are found in MWI ashes. As MWI ashes have not melted, the heavy metals are not incorporated in a mineral matrix as in slags. Additionally, MWI ashes are often used in construction material recycling or simple landfills. Both options may include wash outs or other dissipative fates.

While there is actually no harm to the environment or any public health concern, a further derogation will keep the status and the heavy metals in the economic cycle. There is of course always the general concern of how the existing system will work and whether “dissipative” uses (export, incorporation in other recycling streams, losses) will occur over time.

## 5.2 Technical Feasibility

For technical feasibility we have selected the indicators shown in Table 5-3.

### Table 5-3: Technical Feasibility Indicators Considered

| Indicator | Impact |
|---|---|
| **Technical feasibility** | This indicator estimates the technical feasibility via the current position of the options: established, available, lab-scale. |
| **Action needed** | Based on the technical feasibility and estimated prospect this indicator estimates further action needed or potential barriers to the option. |
| **Estimate of time before activity can occur** | Estimates the minimum time necessary before the activity can occur, if the financial needs and funding are met. |

Table 5-4 shows a rough estimate on the technical feasibility. The Option 3 technologies, together with the business as usual option, are established schemes or processes. During a phasing out we estimate restrictions for MWI as for HWI. The higher HM contents as MWI ash might redirect the normal recovery path or lead to input restrictions.

The four processes have different maturities. Incineration plants exist and are in operation while the plastic-to-oil needs some process adaption and the extraction further basic development.

The further derogation option is the only option without limitation. The option 3, MWI or HWI, have some capacity but for a total phasing out there is doubt that the MWI can dispose the large amounts of plastic crates and pallets. As most of the HWI plants operate on liquid chemicals the capacity for plastic crates and pallets will be limited.

Both processes – extraction and plastic-to-oil – need further developing time and both currently lack resources or funds. Both processes are also highly specific for the treatment of heavy metal containing plastics. Because there is no demand or market for treatment capacity these options will not be realised with respect to the current condition.

### Table 5-4: Technical Feasibility Assessment

| | **Business as usual:** Further derogation | **Option 1:** Extraction | **Option 2:** Plastic-to-oil | **Option 3:** MWI | **Option 3:** HWI |
|---|---|---|---|---|---|
| **Technical feasibility** | Established | Lab-scale | Design / testing needed | Available | Available |
| **Action needed** | No | Funding for basic research & upscaling | Funding or orders | Investigation of potential capacity restriction | Investigation of potential capacity restriction |
| **Estimate of time before activity can occur** | Available now | 5 years | 1 year | Available now | Available now |

## 5.3 Cost Structure

A change from the actual cost of heavy metal containing crates to a heavy metal free crate can be calculated from cost figures provided by Hilche [GDB (2014)] or Nieroda [BB (2014)] for a 1.7 kg mineral water crate and an average 3.7 kg beer crate.

### Table 5-5: Cost Estimate for Beverage Crate Production and Disposal

| | Mineral water | Beer |
|---|---|---|
| | Cost (€/per kg crate) | |
| **Cost of remoulding crates with own plastic (1)** | 1.5 | 1.2 |
| **Cost of new crates from primary plastic (2)** | 2.9 | 2.3 |
| **Cost of extraction of HM (3)** | 0.8 to 1.2 | 0.8 to 1.2 |
| **Disposal (4)** | 2.4 | 2.2 |
| | | |
| **Business as usual (over a life cycle): Cost of crate replacement with derogation (1)** | 1.5 | 1.2 |
| **Option 1: Cost of crate replacement where HMs are extracted (1+3)** | 2.3 to 2.7 | 2.0 to 2.4 |
| **Options 2 and 3: Cost of crate replacement from virgin plastic where HM crates are disposed (2+4)** | 5.3 | 4.5 |

For mineral water crates, the remoulding of owned, heavy metal containing crates costs 1.5€/kg. The manufacture of heavy metal free crates from virgin plastic is estimated to cost 2.9€/kg. Disposal of heavy metal containing crates is estimated to cost 2.4€/kg [GDB (2014)]. The extraction of HM from recyclates cost approx. 0.8-1.2€/kg. Please note that this cost is a very rough estimate based on a 10000 t/a plant (8 years depreciation, within battery limits, no development cost included).

Taking the mineral water crate example, the cost for a "derogation" scenario over a life cycle would be just the remoulding cost of 1.5€/kg.

The cost for extracting HM from HM-recyclates (option 1) is taken to be roughly 0.8-1.2 €/kg and remoulding adds 1.5 €/kg for mineral water crates. The total cost for this option is therefore 2.3-2.7 €/kg, though it must be stressed that these costs are rough potential estimates, and market capacity is currently lacking for this technology which has so far only been tested at the laboratory scale.

The cost for a disposal scenario (options 2 and 3) would add the cost of new crates from virgin material (2.9€/kg) plus the disposal cost (2.4€/kg), resulting in 5.3 €/kg. Therefore, the additional cost of exchanging the heavy metal containing crates for new heavy metal free crates would be 3.8 €/kg over the life cycle.

The total stock of heavy metal containing crates is estimated to be more than 200 million units alone in Germany or 0.58 million tonnes. The disposal options would therefore result in additional costs of approximately € 2.7 billion compared to a continued derogation.

**Table 5-6: Turnover of beer and mineral water producers in Germany and replacement cost**

| Producer | Turnover (million €) | HM crates (tonnes) | Full replacement cost (million €) | Replacement cost in a cycle (ex production) (million €) | Full replacement cost / Turnover (%) |
|---|---|---|---|---|---|
| Beer | 7800 | 444000 | 1980 | 1440 | 25% |
| Mineral water (GDB) | 3200 | 136000 | 720 | 520 | 23% |

If we compare the turnover of the two German production sectors (beer and mineral water) with the full replacement cost, the replacement cost accounts for 23-25 % of the turnover. According to stakeholders GDB (2014) and BB (2014), most actors are SMEs which normally lack the profits and the resources to bear the cost because of their declining market share.

## 5.4 Social Impact

In many European countries the beverage business includes many SMEs [EFBW (2014)]. The companies which serve the mineral water market in Germany and operate the GDB pool are all SME. In the beer market 370-400 SMEs supply 25 % of the output not accounting for the "micro-breweries" which only serve in their own restaurants and normally do not own crates.

Market observers [EFBW (2014)] suggest that especially the market served by SMEs is ripe for consolidation: the market is maturing and the volume is stagnating at best, if not declining. Additionally, the market structure has changed in recent decades: the growing numbers of discounters are only asking for beverage in one-way containers.

For large companies the situations is different as many already own HM-low crates (Heineken, Karlsberg) and are active in both markets: refill bottles and one-way containers. They also have the resources and capital needed to buy HM-low crates. In the past these companies have already shown that they are willing to invest and buy new crates for special designs, colour etc. if they expect that this change in design "buys" them additional markets.

Experts GDB (2014), BB (2014) and EFBW (2014) agree that in case the derogation were discontinued and the companies had to use heavy metal-free crates the beverage and beer market will more or less change as follows:

- The beverage market will tend to use one-way containers. In contrast to beer, beverages are sold by discounters in one-way packaging as the PET one-way bottle. The market share of the SMEs producing plastic crates will decline. Some SMEs will change to heavy metal-free crates as long as their local market gives them reasonable profits.

- The beer market is very conservative, but differs from MS to MS. Where the UK customer seems to prefer cans, the Germans seem to prefer refilled glass bottles as the introduction of cans and PET bottles in the 1990s in Germany did not result in higher market shares. An alternative may be the one-way glass bottle as the success in Benelux has shown. Therefore, the companies will mostly continue with glass bottles and possibly with crates.

# 6.0 Conclusions

Although new robust and reliable quantification has not been able to be determined from the information gathered during this study, it would appear that little has changed over the past five years. The main MS where the more significant quantities of HM crates and pallets occur are Germany, Belgium, the Netherlands, Austria, France, Italy and Spain. The best available estimates of total quantities of affected packaging give a range of 0.7 – 2.4 million tonnes of plastic crates and pallets with a heavy metal concentration exceeding the 100ppm limit.

It appears there has been limited phase out of HM crates and pallets in recent years and there remains an interest in considering alternatives to allowing the continued derogation which is in place, amongst others, to give time to the industry to replace the HM crates and pallets using the best available technique.

The analysis undertaken in the sections above seeks to explore more detailed considerations related to alternatives to the current arrangements for plastic crates and pallets. The summary given in Table 6-1 shows the major positive or negative effects for the four investigated alternatives to a continued derogation for plastic crates and pallets.

### Table 6-1: Comparison of Options

| Impact | **Business as usual:** Further derogation | **Option 1:** Extraction | **Option 2:** Plastic-to-oil | **Option 3:** MWI* | **Option 3:** HWI** |
|---|---|---|---|---|---|
| **Environmental advantage** | = | - | - - / - - - | - - - | - - - |
| **Technical feasibility** | = | - - - | - - | - | = |
| **Capacity availability** | = | ? / - - - | ? / - - | - | - - |
| **Cost** | = | ? / - - | - - | - - | - - - |
| **Social** | = | - - | - - | - - | - - |

| Sign | Significance relative to continued derogation |
|---|---|
| +++ | Substantial positive effect |
| ++ | Positive effect |
| + | Slight positive effect |
| = | No effect |
| - | Slight negative effect |
| - - | Negative effect |
| - - - | Substantial negative effect |
| ? | Unknown |

***MWI =** Municipal waste incineration

****HWI =** Hazardous waste incineration

Continuing the derogation and material recycling is assessed as the best overall solution currently. This option avoids the significant additional costs associated with the alternative options and has negligible health and environmental impacts. The other options are also evaluated to perform worse (or the same) in terms of technical feasibility, available capacity and social impacts.

Under none of the assessment criteria has a positive effect been identified for any alternatives to a continued derogation. All options add significant costs to industry, which could cause a market restructuring where established multi-use systems may be replaced by more one-way oriented distribution systems. This may typically impact on SMEs who are involved in returnable beverage systems.

Options 1 and 2 are not established treatment options for heavy metal containing plastic. Both have yet to prove their technical feasibility in a commercial setting. The potential for future available capacity is unknown. Both options would need further development and funding before they can be considered as serious alternatives to a continued derogation.

Option 3 MWI (municipal waste incineration) is an established treatment method. Crates from households or in small quantities can be handled in MWI as a by-feed to municipal waste. However, it is unclear whether MWIs hold permits to treat heavy metal containing RTP from beverage operators. If MWI have to dispose plastic crates and pallets in a higher amount during a phasing out scheme, the high heating value may lead to capacity shortage and the high heavy metal content may restrict the recycling pathways for ashes.

Option 3 HWI (hazardous waste incineration) lacks the capacity to treat significant quantities of HM crates and pallets. According to one source the total available capacity of HWI is estimated to 0.55 million tonnes per year (Tillmann 2012). Taking into account the rough estimate of 2.5 million tonnes of heavy metal containing RTP calculated by BIO-IS (Bio 2008) the capacity of HWI in Europe would be blocked for nearly 5 years for treating heavy metal containing RTP alone.

Time may be an important issue were the derogation to be revoked or revised. The calculated costs for RTP are based on the typical life expectancy for a crate in circulation of 10 to 25 years.

The additional costs of 3.8€/kg in case the derogation would be discontinued would be very high in relation to the turnover of the affected sectors.

Technical issues significantly hamper the conversion from heavy metal containing RTP to heavy metal free RTP:

- The capacity for the production of a new stock in a short time for the crates and pallets is not available. The cost of new investment is very high because this will be a short business activity and after replacement the activities will immediately decrease. (Bio 2008, PRE 2014)
- The capacity for recovery or disposal is not available or is restricted.

- Special recovery options such as extraction and plastic-to-oil need further development.
- The SMEs in the beverage and beer sectors would be significantly affected in case the derogation for heavy metal containing crates and RTP would be discontinued (EFBW 2014, GDB 2014).

On this basis, a further derogation is assessed as the best option on environmental grounds. It is also cost effective and does not harm SMEs who are invested in the returnable packaging items. However, in this situation no phasing-out of heavy metals takes place.

For extraction or advanced thermal processes, there is a need either for funding or for creating the business case for wide scale take-up of the technologies for treatment of HM-laden packaging through revision of the policy. Currently there is no market for this treatment technology. The processes are highly specific and need technical adaption or further development. Since a thermal approach results in HM content passing to a further waste stream that needs to be managed, only the extraction technology could hope to have an attractive environmental proposition – though the fate of the HM content would still need to be carefully considered.

As the Member States implementation reports over the period 2010-2012 did not provide sufficient information on the functioning of the system and the progress made in phasing out HM plastic crates and pallets, it could not be concluded that indeed all conditions for the derogation are currently fulfilled. Further information should be requested from and provided by Member States.

# 7.0 Stakeholders Contacts and References

## 7.1 Stakeholder Contacts other than Member States

The following persons were interviewed by phone:

| Person | Organisation | Objective | Cited as |
|---|---|---|---|
| **T. Hilche** | Genossenschaft Deutscher Brunnen (Cooperative of mineral water producers), Germany | Crates for bottled water | GDB (2014) |
| **A. Nieroda** | Brauer Bund (brewers association), Germany | Crates for beer | BB (2014) |
| **A. Mäurer** | Fraunhofer Institute for Process Engineering and Packaging IVV (Fhg-IVV) | Recycling, HM extraction | Mäurer (2014) |
| **A. THEES-OVELGÖNNE** | Plastics Recyclers Europe | Plastic Recycling | PRE (2014) |
| **Antonio Furfari** | Plastics Recyclers Europe | Plastic Recycling | PRE (2014) |
| **Wolf-Eberhard Nill** | Nill-Tech | HM extraction | Nill (2014) |
| **D. Gross** | Wirtschaftvereinigung Alkoholfreie Getränke (Association of non-alcoholic beverages), Germany | Softdrink industry | Wafg (2014) |
| **Heinrich** | GVM | Monitoring report | GVM (2014) |
| **Kremer** | recrate | Monitoring | Recrate (2014) |
| **Patricia Fosselard** | European Federation of Bottled Water | Crates, beverage | EFBW (2014) |
| **Anna-Maria De Smet** | Brewers of Europe | Crates, brewers | EFBW (2014) |
| **Arno Dopychai** | German Mineral Water Association | Crates, beverage industry | EFBW (2014) |

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| | |
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| **Tillman (2012)** | David A. Tillman, Incineration of Municipal and Hazardous Solid Waste, Elsevier 2012. |
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