Journal of Environmental Management 212 (2018) 108–114

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Risk management of hazardous substances in a circular economy

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ARTICLE INFO

Article history:
Received 18 October 2017
Received in revised form
9 January 2018
Accepted 2 February 2018

Keywords:
Chemicals
Recycling
REACH
Toxicity
Sustainability

ABSTRACT

The ambitions for a circular economy are high and unambiguous, but day-to-day experience shows that the transition still has many difficulties to overcome. One of the current hurdles is the presence of hazardous substances in waste streams that enter or re-enter into the environment or the technosphere. The key question is: do we have the appropriate risk management tools to control any risks that might arise from the re-using and recycling of materials? We present some recent cases that illustrate current practice and complexity in the risk management of newly-formed circular economy chains. We also highlight how separate legal frameworks are still disconnected from each other in these cases, and how circular economy initiatives interlink with the European REACH regulation. Furthermore, we introduce a novel scheme describing how to decide whether a(n)(additional) risk assessment is necessary with regard to the re-use of materials containing hazardous substances. Finally, we present our initial views on new concepts for the fundamental integration of sustainability and safety aspects. These concepts should be the building blocks for the near future shifts in both policy frameworks and voluntary initiatives that support a sound circular economy transition.

1. Introduction

Building on the global Sustainable Development Goals (SDGs; UNEP, 2016), the circular economy concept has become a particular area of focus in many countries. Both biotic and abiotic waste streams are increasingly used in a variety of circular economy technologies. Biotic waste originates primarily from agricultural or forestry activities and may serve as a bio-based, renewable feedstock for both producing bio-energy (e.g. biogas) and manufacturing bio-based products. Abiotic waste comprises a wide range of material streams such as plastics, metals, paper, construction materials, and wastewater.

The re-use or recycling of these waste streams fits within the ambitions of many national and international sustainability objectives focusing on the reduction of the use of fossil feedstocks and on resource efficiency (European Environment Agency, 2016). The Dutch House of Representatives recently stated that, in 2030, the use of primary raw materials (minerals, fossils and metals) has to be reduced by 50% (Dutch Parliamentary document, 2016). Partly, this should be achieved by increasing the current efficiency of resource use and by further optimising recycling, hence reducing waste and the use of primary raw materials. The other part should be reached by increasing the contribution of biomass as a renewable resource, and cascading and optimising the use of this resource. In addition to resource efficiency, a circular economy offers substantial opportunities for reducing CO_2 emissions (Paris Protocol; European Commission, 2015). Greater efficiency in raw material and material chains could save 17 megatonnes of CO_2 equivalents annually in the Netherlands, being nearly 10% of its annual production of CO_2 (Dutch Parliamentary document, 2016).

The ambitions for a circular or biobased economy are high and unambiguous. Day-to-day experience, however, makes it very clear that the transition still has many difficulties to overcome. One of the current hurdles is the presence of hazardous substances in waste streams that enter or re-enter into the environment or the technosphere. Examples are stabilising agents in PVC (e.g. Pivnenko et al., 2016), plasticisers in food packaging materials (e.g. Vápenka et al., 2016), but also chemicals that were unintentionally formed during processing, like furans, dioxins or polycyclic aromatic hydrocarbons (e.g. Tue et al., 2013). An important category comprises the so-called ‘legacy substances’ which are prohibited or severely restricted by law nowadays, but may still be present in numerous materials. These hazardous chemicals may re-emerge in the end-

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https://doi.org/10.1016/j.jenvman.2018.02.014
0301-4797/© 2018 Published by Elsevier Ltd.

products that are manufactured from waste, resulting in potential risks for mankind and the environment. The substances may also pose hitherto unidentified risks because of different exposure and environmental emission routes from the new waste processing technologies compared to the conventional treatment. The key question is, therefore, do we have the appropriate risk management tools to control any risks that might arise.

The European framework for the concepts of waste, by-product and end-of-waste status, in practice, leads to considerable (legal) uncertainty, especially in connection with REACH, the most important regulation on the risk management of chemicals in the EU (Regulation (EC) No 1907/2006; European Commission, 2006). REACH was set up to take into account the potential risks during the entire life cycle of chemicals, including the waste phase, but, in practice, the focus has been on the production and use stages of substances. Waste legislation and substance-specific legislation have been 'living apart' for decades, but recent circular economy initiatives are now forcing them together in an accelerated way. This alliance, aimed at the seamless application of waste as a valuable resource, has led to many debates in public and political arenas, but also caused uncertainties for companies and authorities.

Beyond doubt, a circular economy demands a shift in societal views on the status of waste. The main challenge is to find the right balance between, on the one hand, sustainability targets such as resource efficiency and the reduction of greenhouse emissions and, on the other hand, environmental public safety and health targets. Such a 'reset' is not only needed from a legal point of view, but also from a scientific one, i.e. we have to find other, more integrated assessment and weighting mechanisms to assess both sustainability and safety aspects.

In this article, we present some recent cases that illustrate current practice and the complexity of the risk management of newly-formed circular economy chains. We will also highlight how separate legal frameworks are still disconnected from each other in these cases, and how circular and bio-based chemistry initiatives interlink with the REACH regulation. Finally, the focus is put on the way forward, presenting our views on new concepts for the integration of sustainability and safety aspects. With respect to safety aspects, we will present a novel scheme which describes how to decide whether a(n)(additional) risk assessment is necessary with regard to the re-use of materials containing hazardous substances. This pragmatic risk management approach aligns with the European policy strategy towards a non-toxic environment, which was announced in the EU's 7th Environmental Action Plan (European Commission, 2014) as well as with the UNEP SDGs.

2. Case studies

2.1. Lead in ray tubes

Waste from cathode ray tubes (CRT) from TV sets, computer monitors, etcetera contains lead. Lead is toxic for reproduction and for the development of children. Because of the toxicity of lead, a thorough assessment is needed when lead-containing waste is re-used in new products. Spijker et al. (2015) studied the prerequisites for the re-use of the material. CRT waste can be processed by grinding it into glass granulate. The granulate is labelled hazardous waste under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (UNEP, 1989) because of the high lead content.

The presence of lead makes it difficult for the granulate to be re-used in new, safe products. One of the applications of CRT granulate is to use it as aggregate in concrete, replacing natural sand and gravel. This is presumed to be a safe application, because the lead is not released from the concrete. Concrete construction elements containing CRT glass granulate are brought to the Dutch market and comply with the Dutch quality criteria on construction products (Besluit Bodemkwaliteit, 2007). These quality criteria are based on the release of hazardous substances during the use phase rather than on chemical composition. Lead, i.e. lead mono-oxide, is rated a Substance of Very High Concern (SVHC) within REACH. The concrete elements are regarded as articles, for which, to date, in the scope of REACH, no restrictions apply other than the obligation to submit a notification of the presence of the chemical in the article (above 0.1% by weight and above 1 tonne per year). Furthermore, the obligation holds to communicate the presence of this chemical downstream in the supply chain (see Section 3.1). Both Dutch and EU regulations allow these concrete elements with CRT granulates as a product on the market, assuming that it will be safe. While (theoretically) safe during use, there is a problem when this concrete is turned into waste. This waste is also considered to be hazardous waste because of the presence of lead, as is shown by calculations based on data from literature on lead in CRT glass (Spijker et al., 2015). As a consequence, when CRT glass is re-used in concrete elements an up to three times larger volume of hazardous waste will be created in the future, with no current recovery options available. Mixing lead-containing concrete waste with non-hazardous concrete waste is not allowed. Therefore, concrete waste containing CRT aggregates must be processed separately from other concrete waste. However, there is no way to discern hazardous concrete from non-hazardous concrete and therefore, it can be expected that streams will sooner or later mix.

This case is a clear example where assumptions about safety, or acceptable risk, during the use phase do not take into account the future life cycle stages of the material. Both expected outcomes of this case, a three times larger volume of hazardous waste or mixing hazardous and non-hazardous waste, may be considered unacceptable from a safety point of view.

2.2. HBCDD in expanded polystyrene (EPS)

Expanded polystyrene (EPS) is used as packaging material, in fish boxes for example, but also for building and construction purposes (Albrecht and Schwitalla, 2014). The 1973 oil crisis stimulated its production enormously as numerous energy efficiency policies were released (Pohleman and Echte, 1981; Giebeler et al., 2009). EPS is highly combustible and, for safety reasons, the flame retardant hexabromocyclododecane (HBCDD) has generally been added to EPS construction and building materials at concentrations of about 0.7% w/w. The application of EPS in buildings and road works has left us with a considerable legacy of the persistent organic pollutant HBCDD. In Germany it is estimated that, between 1980 and 2012, about 35,000 tonnes of HBCDD was used in 253,000,000 m^3 EPS. In the Netherlands about 4000 tonnes of HBCDD was used between 1960 and 2015. HBCDD-containing polystyrene from buildings and construction is expected to find its way to the waste stage in the next 50 years (Albrecht and Schwitalla, 2014).

HBCDD is now regulated through different European regulations addressing both the waste stage and the application in new and recycled materials. In 2008 HBCDD was brought to the Candidate List as an SVHC under the REACH regulation and, in 2011, it was subsequently added to the REACH Authorisation List (Annex XIV). This means that HBCDD could be used until August 2015 and that its use after that date is permitted only if it is authorised by the European Commission (see Section 3.1). In 2013 the Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2001) decided to include HBCDD in Annex A of the Convention, aimed at elimination. The European POP Regulation (EC Regulation 850/2004; European Commission, 2004), which is an implementation of