ARTICLE IN PRESS

Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

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

Methods to estimate the transfer of contaminants into recycling products – A case study from Austria

Julika Knapp [a,*], Astrid Allesch [b], Wolfgang Müller [a], Anke Bockreis [a]

[a] Universität Innsbruck, Unit for Environmental Engineering, Section of Waste Treatment and Resource Management, Austria
[b] TU Wien, Institute for Water Quality, Resource and Waste Management, Austria

ARTICLE INFO

Article history:
Received 11 February 2017
Revised 3 July 2017
Accepted 21 August 2017
Available online xxxx

Keywords:
Recycling
Transfer of contaminants
Waste wood
Recycled construction materials
Compost
Plastic waste

ABSTRACT

Recycling of waste materials is desirable to reduce the consumption of limited primary resources, but also includes the risk of recycling unwanted, hazardous substances. In Austria, the legal framework demands secondary products must not present a higher risk than comparable products derived from primary resources. However, the act provides no definition on how to assess this risk potential.

This paper describes the development of different quantitative and qualitative methods to estimate the transfer of contaminants in recycling processes. The quantitative methods comprise the comparison of concentrations of harmful substances in recycling products to corresponding primary products and to existing limit values. The developed evaluation matrix, which considers further aspects, allows for the assessment of the qualitative risk potential.

The results show that, depending on the assessed waste fraction, particular contaminants can be critical. Their concentrations were higher than in comparable primary materials and did not comply with existing limit values. On the other hand, the results show that a long-term, well-established quality control system can assure compliance with the limit values. The results of the qualitative assessment obtained with the evaluation matrix support the results of the quantitative assessment. Therefore, the evaluation matrix can be suitable to quickly screen waste streams used for recycling to estimate their potential environmental and health risks. To prevent the transfer of contaminants into product cycles, improved data of relevant substances in secondary resources are necessary. In addition, regulations for material recycling are required to assure adequate quality control measures, including limit values.

1. Introduction

Global population growth, accelerated industrialisation and urban development have led to an continuous increase of natural resource consumption and waste generation on a global basis (Sharma et al., 2017). The worldwide generation of municipal solid waste is estimated in a range between 1.5 and 2 billion tons per year (Sharma et al., 2017; Zaman, 2016). About 84% of the generated waste is collected, and the major part of the collected waste is still disposed in landfills (Zaman, 2016). Due to the negative impacts of inadequately stored solid waste on the environment and the climate, the waste sector is a necessary part of the sustainability agenda (Pietzsch et al., 2017; Silva et al., 2017). Waste policies are increasingly taking into account the concepts of sustainable production and consumption and circular economy moving on from the 'prevention of waste' to recognising individual wastes as a resource (Silva et al., 2017). However, as described by Ghisellini et al. (2016), circular economy implementation still seems to be in its initial stages, majorly focused on recycling. Important results that have been achieved so far are high waste recycling rates in selected developed countries (Ghisellini et al., 2016). In this context the European Union introduced a directive to facilitate the transition to a more circular economy, proposing minimum recycling targets of 65% for municipal solid waste and of 75–85% for packaging waste by 2030 (European Commission, 2015).

While high recycling rates are an important step towards a circular economy (Zaman, 2016; Zaman and Lehmann, 2011), this quantitative approach does not take into account the presence of unwanted, hazardous substances ending up in the second generation products (Kral et al., 2013). According to Pivnenko (2016) the presence of such chemicals in materials for recycling has not been systematically investigated. He called attention to the potential trade-offs between material quantity (i.e. recycling rates) and quality (i.e. presence of contaminants), and demonstrated that material

* Corresponding author.
E-mail address: julika.knapp@uibk.ac.at (J. Knapp).

http://dx.doi.org/10.1016/j.wasman.2017.08.035
0956-053X/

recycling should be a conscious balance between high quality (secondary) products and high (mass based) recycling rates (Pivnenko et al., 2016b). Also Brunner (2010) concluded that recycling strategies should focus not simply on increasing recycling quantities, but recycling qualities should be favoured, and Brunner and Rechberger (2015) emphasised that recycling must generate "clean" cycles, separating harmful impurities from valuable materials. Kral et al. (2013) highlighted that such a "clean cycle" strategy will result in better recycling qualities of secondary products and less dissipation of hazardous substances during further product use. Careful planning and performance evaluation of recycling schemes are important to ensure a high quality of collected recyclables, and the assessment of environmental impacts is becoming increasingly important to ensure that recycling schemes do not shift environmental burdens to other parts of the waste management system (Götze et al., 2016).

Regarding recycling in Austria, the legal framework demands secondary products produced from recycled wastes must not present a higher risk than comparable products derived from primary resources (Austrian Federal Government, 2002). Based on the project "Benchmarking of the Austrian Waste Management System" (Allesch and Brunner, 2016; Brunner et al., 2015), the objectives of this paper were to analyse different methods for the estimation of contaminant transfer to recycling products, which could result in risks to human health and to the environment.

2. Materials and methods

2.1. Description of the assessed wastes/recycling products

Based on Brunner et al. (2015), four waste fractions/recycling products were selected for assessment due to their relevance in terms of environmental and health risks in secondary products: (1) waste wood, (2) recycled construction materials (RCM) produced from construction and demolition (C&D) waste, (3) composts produced from biogenic wastes, and (4) plastic wastes. In Tables 1–4 the key characteristics of these waste fractions regarding recycling in Austria are summarised.

2.2. Methods: Quantitative and qualitative assessment

The Austrian Federal Waste Management Act demands "recycling products must not present a higher risk potential than comparable primary resources or products". However, the act provides no definition on how to assess the risk potential. The lack of this information results in methodological challenges when assessing whether recycling poses environmental or health risks.

In this paper, "risk potential" is defined as the risk posed by the undesired recycling of substances, toxic to humans or the environment, when recycling wastes. For the assessment, quantitative and qualitative approaches were introduced and compared. The quantitative approaches focused on the concentrations of harmful substances in wastes/recycling products compared to the concentrations in primary resources/products and to existing limit values. For further consideration of direct and indirect influences, an evaluation matrix was developed for qualitative assessment.

The quantitative assessment was based on a comprehensive material flow analysis at the level of goods and eleven selected indicator substances (cadmium, carbon, chromium, copper, iron, lead, mercury, nickel, nitrogen, phosphorus, zinc), conducted with the free software STAN (Cencic and Rechberger, 2008). Detailed information on substance concentrations and transfer coefficients are provided in Brunner et al. (2015). In addition, a literature review was conducted to collect data on substance concentrations in primary and secondary resources/products.

Table 1
Characterisation of waste wood and wood residues and their recycling in Austria.

Generation (BMLFUW, 2016)		• About 4,700,000 tons per year, composed of 3,500,000 tons wood residues and 1,200,000 tons waste wood
Composition (BMLFUW, 2016)		• Rind, splinters of natural, clean, uncoated wood (39% of the total amount) • Sawdust and shavings of natural, clean, uncoated wood (24%) • Bark (19%) • Building and demolition wood, wooden packaging, bulky waste wood from households and not contaminated waste wood, chipboard waste (~16%) • Impregnated or organically treated wood, and waste wood classified as hazardous (e.g. railway sleepers, stakes and poles) (~2%)
Material recycling (Svehla and Winter, 2013)	*Amount of recovery*	• About 400,000 tons per year of waste wood are used for manufacturing in the wood-processing industry.
	Area of application	• Waste wood is mainly used to produce chipboards (particle boards). Chipboards can contain about 30–50% waste wood.
	Risk potential	• Waste wood can be contaminated by various organic or inorganic contaminants due to wood preservation agents like varnishes and stains, or by coatings.

Table 2
Characterisation of C&D waste and C&D waste recycling in Austria.

Generation (BMLFUW, 2016)		• 9,500,000 tons per year of C&D waste
Composition (BMLFUW, 2016)		• Concrete demolition waste (37% of total amount) • Building debris (no construction site waste) (29%) • Demolition bitumen and asphalt (17%) • Road rubble (9%) • Construction site waste (no building debris) (3.5%) • Track ballast (2.5%) • Other mineral waste from construction (2%)
Material recycling (BMLFUW, 2016)	*Amount of recovery*	• About 8,700,000 tons per year of C&D waste are recovered as recycled construction materials (>90% recovery).
	Area of application	• Recycled construction materials are used for: – Structural and geotechnical engineering – Road, bridge and railway constructions
	Risk potential	• Construction and demolition waste can be contaminated by various organic or inorganic contaminants. Contamination can be caused in the usage phase and by demolition practices, but also originate from primary materials, e.g. high geogenic concentrations of heavy metals in rocks.

Please cite this article in press as: Knapp, J., et al. Methods to estimate the transfer of contaminants into recycling products – A case study from Austria. Waste Management (2017), http://dx.doi.org/10.1016/j.wasman.2017.08.035