Waste Management xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

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

# Waste paper for recycling: Overview and identification of potentially critical substances

Kostyantyn Pivnenko *, Eva Eriksson, Thomas F. Astrup

*Department of Environmental Engineering, Technical University of Denmark, Miljøvej Building 113, DK-2800 Kgs. Lyngby, Denmark*

ARTICLE INFO

*Article history:*
Received 5 November 2014
Accepted 23 February 2015
Available online xxxx

*Keywords:*
Hazardous substances
Paper
Priority pollutants
Recycling
Waste management

ABSTRACT

Paper product manufacturing involves a variety of chemicals used either directly in paper and pulp production or in the conversion processes (i.e. printing, gluing) that follow. Due to economic and environmental initiatives, paper recycling rates continue to rise. In Europe, recycling has increased by nearly 20% within the last decade or so, reaching a level of almost 72% in 2012. With increasing recycling rates, lower quality paper fractions may be included. This may potentially lead to accumulation or un-intended spreading of chemical substances contained in paper, e.g. by introducing chemicals contained in waste paper into the recycling loop. This study provides an overview of chemicals potentially present in paper and applies a sequential hazard screening procedure based on the intrinsic hazard, physical–chemical and biodegradability characteristics of the substances. Based on the results, 51 substances were identified as potentially critical (selected mineral oils, phthalates, phenols, parabens, as well as other groups of chemicals) in relation to paper recycling. It is recommended that these substances receive more attention in waste paper.

© 2015 Elsevier Ltd. All rights reserved.

## 1. Introduction

Paper recycling is one of the most well-established recycling schemes applied to waste materials today. Recycled paper is an integral part of paper and pulp production, with estimated utilisation for recycling in Europe of about 72% in 2012 (an increase of 20% from 2000) (CEPI, 2013a). In addition to recycled paper being an important raw material for the paper industry (CEPI, 2013b), it has also been demonstrated in several studies that paper recycling may offer significant environmental benefits in a lifecycle perspective (Laurijssen et al., 2010; Villanueva and Wenzel, 2007). Thus, paper recycling may be regarded as beneficial from both a resource and an environmental perspective and should be promoted as much as possible. However, increasing concerns related to the presence of potential harmful chemical substances in paper have been voiced within recent years (e.g. Biedermann et al., 2011b; Liao and Kannan, 2011; Pivnenko et al., 2013), for example in relation to the migration of chemicals from packaging materials into food (e.g. Begley et al., 2008; Biedermann et al., 2013; Gärtner et al., 2009; Lorenzini et al., 2013). While further increasing paper recycling rates can undoubtedly be achieved in Europe, the quality of the waste paper may ultimately decrease as more and more "marginal" paper fractions are collected for recycling and the contents of harmful substances in paper thereby increase. A systematic overview of the chemical substances potentially present in waste paper for recycling is therefore needed to provide a basis for further evaluation of the quality of waste paper as a resource, and ultimately also to maintain consumer acceptance of recycled paper in general.

Paper production and manufacturing operations generally consist of the following two phases: (i) paper and pulp production by the paper industry (i.e. different quality grades of paper) and (ii) paper product manufacturing by separate industries (e.g. periodicals, packaging materials, books, etc.). Chemicals in waste paper may originate from a wide range of sources, namely intentionally added (i.e. additives, inks, pigments, glues, etc.), part of a reaction and/or biodegradation or added during the use phase of the paper

*Abbreviations:* BBP, Benzyl butyl phthalate; BPA, Bisphenol A; CAS, Chemical Abstracts Service; CEPI, Confederation of European Paper Industries; DBP, Dibutyl phthalate; DEHP, Diethylhexyl phthalate; DIBP, Diisobutyl phthalate; DIPN, Diisopropyl naphthalene; EDCs, Endocrine Disrupting Chemicals; EFSA, European Food Safety Authority; EuPIA, European Printing Ink Association; FDHA, Swiss Federal Department of Home Affairs; NIAS, Non-Intentionally Added Substances; PCBs, Polychlorinated biphenyls; PBT, Persistent Bioaccumulative and Toxic; vPvB, very Persistent and very Bioaccumulative; ZELLCHEMING, Vereins der Zellstoff- und Papier-Chemiker und -ngenieure (German for: Association of Chemical Pulp and Paper Chemists and Engineers).

* Corresponding author. Tel.: +45 4525 1602; fax: +45 4593 2850.
*E-mail address:* pivnenko.k@gmail.com (K. Pivnenko).

http://dx.doi.org/10.1016/j.wasman.2015.02.028
0956-053X/© 2015 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Pivnenko, K., et al. Waste paper for recycling: Overview and identification of potentially critical substances. Waste Management (2015), http://dx.doi.org/10.1016/j.wasman.2015.02.028

or during the waste management phase (e.g. cross-contamination from other waste materials during collection). Chemicals are added in order to improve the production process itself and the quality or functionality of the final product. Starting with paper production, chemicals are introduced through the use of synthetic additives, which include retention aids, sizing agents, coatings, biocides, synthetic binders, etc. Synthetic additives represent slightly more than 1% v/v of raw materials used in paper production (ZELLCHEMING, 2008), the largest share of which (90% v/v) are functional additives (Moench and Auhorn, 2002) intended to be retained in the paper product. The next step, where the paper is converted into a final product, may include printing, dyeing, addition of adhesives and labels, etc. During the processing, chemicals may dissolve and be removed via wastewater, volatilise and be released to air or remain in the solid matrix and thereby be present in newly manufactured paper products. When waste paper is added to the process, this may potentially introduce new substances from the use and waste management phase. Knowing which potential partitioning a given chemical (or group of chemicals) will follow is vital for identifying potentially critical substances which may end up being concentrated in the fibres and be reintroduced into consumer products.

Recent studies have demonstrated that paper and paper products may contain high numbers of chemical substances (BMELV, 2012; Bradley et al., 2008), most of which can be associated with the printing industry, where more than 7,000 chemicals may be used in food-packaging ink production alone (EuPIA, 2012). Nevertheless, very little quantitative information is available regarding the presence of specific substances in paper products or waste paper potentially sent to recycling. Most existing studies target a specific group of chemicals or paper products (e.g. Becerra and Odermatt, 2012; Geens et al., 2012; Song et al., 2000; Trier et al., 2011), and attempting to identify every single chemical present in paper has proved to be challenging (BMELV, 2012).

Although specific regulations covering paper food packaging do not exist, European legislation on items (i.e. plastics, metal, paper, etc.) brought into contact with food prevents the use of chemicals that could migrate into foodstuffs and adversely affect human health, as well as the quality and nature of food (EC, 2004). This legislation covers paper packaging produced from virgin fibres, but when paper is recycled, the producers may not be aware of the presence of any specific chemicals added throughout the lifecycle of the paper. Consequently, the paper industry, and the final output paper quality, is affected by the presence of chemicals in the recycled paper, e.g. chemicals introduced during the use phase or via paper products from other countries. In 2012, more than 5 million tonnes of paper (approx. 11% of recycled paper) was imported into Europe from the USA, Russia, Brazil, Canada, etc. for paper product manufacturing (CEPI, 2013a).

Without a comprehensive overview of which chemical substances should be prioritised in relation to paper, and which substances should ultimately be avoided, it may not be possible in the future to ensure both high recycling rates and at the same time a high quality of the paper products based on recycled fibres. As direct and substance-by-substance analysis is not practically feasible, a systematic screening of un-problematic chemicals is needed, in order to identify those substances which may be considered most problematic and critical for the future recycling of paper.

The overall goal of this study is to provide a basis for systematically addressing the recyclability of waste paper with respect to the potential presence of hazardous substances. The specific objectives are: (i) based on existing literature, to compile a list of chemical substances potentially applied in paper production and paper product manufacturing, as well as chemicals identified directly in paper, (ii) based on a sequential hazard screening procedure to identify the most critical chemicals from this list based on their harmfulness, physical–chemical properties and biodegradability and (iii) to evaluate potential implications related to the management of paper waste and paper recycling.

## 2. Methodology

### 2.1. Data sources for chemicals in paper

Information about chemical substances, used in either paper production or paper conversion, as well as chemicals identified in actual paper product flows, was obtained from a range of data sources. Chemicals used in pulp and paper production were obtained from national product registries (KEMI, 2014; SPIN, 2013) and scientific assessments (Riskcycle, 2013; ZELLCHEMING, 2008), as well as inventory data provided by the European Food Safety Authority (EFSA) (EFSA, 2012a). Substances used by the printing industry were obtained from a recent Danish report (Miljøstyrelsen, 2011a), an inventory list of the European Printing Ink Association (EuPIA) (EuPIA, 2012) and recent regulation issued by the Swiss Federal Department of Home Affairs (FDHA) (FDHA, 2005). Although data obtained for paper printing could not be isolated from the printing of other materials, the European printing industry belongs to a forest-based industrial sector, and the share of paper in the printing industry is substantial. All of the abovementioned data sources predominantly reflected European industry and research; this was not due to any selection of sources, but rather reflected availability of state-of-the-art information and level of detail provided. No information could be found related specifically to chemicals used in adhesives, so these were therefore only indirectly included in the study as part of the analytical literature reviewed. Additionally, relevant scientific literature addressing the composition of paper, paper products or waste paper was reviewed. While the aim was not to provide an exhaustive review of all available literature, the focus was placed on recent literature in order to relate any findings as best as possible to the current technological scope of the paper industry. No geographical scope was applied to the selected studies, as paper is a commodity traded on the global market with high volumes of paper, paper packaging and waste paper being imported and exported on a yearly basis. In total, 25 scientific studies were reviewed. Where available the concentrations of substances mentioned in the literature are also provided. See Table 1 for a complete list of the data sources used in this paper.

Based on the abovementioned combination of information sources, a compilation of almost 10,000 chemical substances was obtained once duplicates were removed. To avoid ambiguity and potential double-counting, only chemicals (or groups of chemicals) which could be assigned a valid CAS (Chemicals Abstracts Service) registry number were included in the study.

### 2.2. Criteria for identifying potential priority chemicals

With the aim of identifying potentially critical chemicals that should be prioritised in relation to paper recycling, a screening selection procedure was applied for those that may be considered most harmful, most likely to be associated with paper fibres (and not volatilise or be released into the water phase during re-pulping) and the most persistent in the environment. The procedure involved the following four steps: (1) compiling an inventory of chemicals that may be used in the paper and printing industries or which may have been identified in paper (corresponding to the list of about 10,000 substances mentioned above), (2) identifying potentially harmful chemicals, (3) identifying chemicals primarily associated with solids (i.e. paper fibres) and (4) identifying chemicals characterised as not readily biodegradable. Steps (1) through (4) were carried out consecutively, thereby filtering out less

Please cite this article in press as: Pivnenko, K., et al. Waste paper for recycling: Overview and identification of potentially critical substances. Waste Management (2015), http://dx.doi.org/10.1016/j.wasman.2015.02.028

Download English Version:

https://daneshyari.com/en/article/6354286

Download Persian Version:

https://daneshyari.com/article/6354286

Daneshyari.com