Science of the Total Environment 575 (2017) 1–5

Contents lists available at ScienceDirect

Science of the Total Environment

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

Review

Innovating e-waste management: From macroscopic to microscopic scales

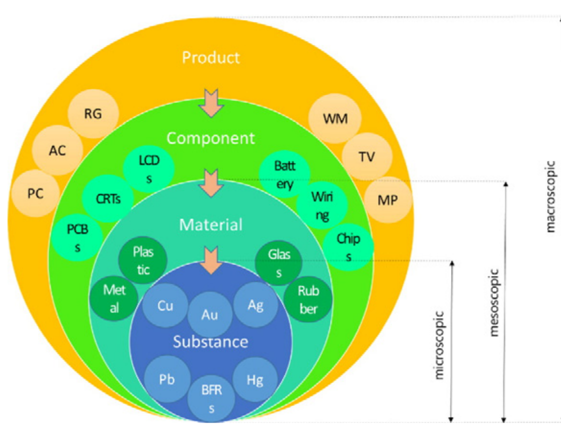
Xianlai Zeng [a], Congren Yang [a], Joseph F. Chiang [b,*], Jinhui Li [a,*]

[a] *Key Laboratory for Solid Waste Management and Environment Safety, School of Environment, Tsinghua University, Beijing 100084, China*
[b] *Department of Chemistry and Biochemistry, State University of New York College at Oneonta, Oneonta, NY 13820, USA*

HIGHLIGHTS

- E-waste management covers four levels of product, component, material, and substance.
- Material compatibility, fatigue, and reclaiming have gained much attention.
- Material fatigue can determine the reverse logistics of e-waste.
- Future management should be concerned from macroscopic and mesoscopic to microscopic scales.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 11 July 2016
Received in revised form 8 September 2016
Accepted 10 September 2016
Available online 7 October 2016

Editor: Simon Pollard

Keywords:
E-waste
Management
Recycling
Macroscopic
Mesoscopic
Microscopic

ABSTRACT

Waste electrical and electronic equipment (WEEE or e-waste) has become a global problem, due to its potential environmental pollution and human health risk, and its containing valuable resources (e.g., metals, plastics). Recycling for e-waste will be a necessity, not only to address the shortage of mineral resources for electronics industry, but also to decline environmental pollution and human health risk. To systematically solve the e-waste problem, more attention of e-waste management should transfer from macroscopic to microscopic scales. E-waste processing technology should be significantly improved to diminish and even avoid toxic substance entering into downstream of material. The regulation or policy related to new production of hazardous substances in recycled materials should also be carried out on the agenda. All the findings can hopefully improve WEEE legislation for regulated countries and non-regulated countries.

© 2016 Elsevier B.V. All rights reserved.

* Corresponding authors.
E-mail addresses: Joseph.Chiang@oneonta.edu (J.F. Chiang), jinhui@tsinghua.edu.cn (J. Li).

http://dx.doi.org/10.1016/j.scitotenv.2016.09.078
0048-9697/© 2016 Elsevier B.V. All rights reserved.

Contents

1. Introduction . . . 2
2. What are the terms of product, component, material, and substance in e-waste recycling? . . . 2
3. Macroscopic-level management for product and component . . . 2
4. Mesoscopic-level management for material . . . 3
4.1. Material compatibility. . . . 3
4.2. Material fatigue . . . 3
4.3. Material reclaiming . . . 4
5. Microscopic-level management for substance . . . 4
6. Conclusions and the way forward. . . . 4
Acknowledgements . . . 5
References. . . . 5

1. Introduction

Since 2000s, waste electrical and electronic equipment (WEEE or e-waste) has become a global concern in terms of environmental improvement and resource recycling (Breivik et al., 2016; Stevels et al., 2013), which is the fastest-growing waste steam with the 43.8 million tons (Mt) global quantity in 2015 and growing to 49.8 Mt in 2018 (Baldé et al., 2015). Currently, China generated approximately 8.53 Mt e-waste in 2014 and has overtaken the USA to become the largest producers (Zeng et al., 2016a).

E-waste contains not only lots of valuable resources (e.g., metals, plastics), but also plenty of toxic materials [e.g. heavy metals, brominated flame retardants (BFRs)] (Chen et al., 2016). Massive e-waste has bred at least two serious global problems: electronics industry sustainability owing to the shortage of mineral resources (Cucchiella et al., 2015), and potential environmental pollution and human health risk subject to informal recycling (Labunska et al., 2015; Zeng et al., 2016b). Conversely, formal recycling of e-waste or urban mining can result in positive environmental, resources and economic benefits (Cucchiella et al., 2016a; Cucchiella et al., 2016b).

However, recycling and deep recovery for valuable resource by dismantling, mechanical–physical, hydrometallurgy or pyro-metallurgy can generate and release heavy metals (e.g., Cu, Pb, Cd, Cr) and persistent organic pollutants (POPs) (e.g., polychlorinated biphenyls, polycyclic aromatic hydrocarbons, polybrominated diphenyl ethers, and polychlorinated dibenzo-p-dioxins and dibenzofurans) (Awasthi et al., 2016; Park et al., 2014; Wu et al., 2016). The heavy metal and POP emission can cause serious environmental problems in some informal recycling sites (Fu et al., 2013; Huang et al., 2016). At the same time, the hazardous substances can enter into new products with valuable material recycling. When using the new products, hazardous substances are distinctly exposed to public environment and human (Chen et al., 2016; Song and Li, 2014).

In order to solve the e-waste problem, the European Union (EU) established *Directive on Waste Electrical and Electronic Equipment* (WEEE Directive) since 2002 (Król et al., 2016; Milovantseva and Fitzpatrick, 2015; Zeng et al., 2013). A series of regulations regarding restriction of the use of hazardous substances in electrical and electronic equipment have been enacted (Li et al., 2015b). Many countries or regions also have set up similarly e-waste legislation (Chung and Zhang, 2011). Simultaneously, the Basel Convention was designed to control transboundary movements of hazardous wastes and their disposal (Ogunseitan, 2013), but some developed countries, like USA, did not ratify the Basel Convention, and exported many e-waste to developing country, such as China and India (Breivik et al., 2014; Hadi et al., 2015; Song et al., 2015).

Therefore, to address e-waste recycling and environmental pollution, we propose that the management of e-waste should cover three levels of macroscopic (product and component), mesoscopic (material), and microscopic (substance) scales.

2. What are the terms of product, component, material, and substance in e-waste recycling?

Material flow occurs from e-waste to final or new products during the recycling process. The term *material* is defined as the substance of which a thing is made or composed of component or constituent matter (Lenton et al., 2016). In chemistry, a *substance* is defined as a single type of matter consisting of uniform units. If the units are atoms, the substance is called an element, such as carbon or iron; if they are molecules, it is called a chemical compound, such as carbon dioxide or iron chloride (Brunner and Rechberger, 2004). A *component* is composed of many materials, and *product* is the mixtures of some components, and can function to serve for people with economic values (positive or negative) assigned by markets.

In light of these rules, e-waste such as waste computer, television, and mobile phone is product; printed circuit boards (PCBs), cathode ray tubes (CRTs), liquid crystal displays (LCDs), battery, wiring, and chips are typical components dismantled from e-waste; metal, plastic, glass, and rubber composed of product or component can be regarded as material; and further copper, gold, silver, lead, mercury, and BFRs are substances (Fig. 1). For example, waste personal computers is product; PCB that dismantled from waste personal computer is components; tin-lead solder that used to fix electronic components on the PCBs can be regarded as material; and further tin and lead are substances. In physical world, product/component, material, and substance will locate in macroscopic, mesoscopic, and microscopic levels, respectively. All in all, towards the e-waste problems solving, adequate attentions by regulation and technology are dominantly fundamental and crucial for various stages of material flow in scientific perspective.

The jigsaw-physical structure of e-waste results in mechanical treatment is the most broadly accepted manner to recycle e-waste from developing countries to industrial nations (Ruan and Xu, 2016; Zhang and Xu, 2016). After simple dismantling, WEEE (e.g. personal computer, air conditioner) can be easily treated for many plastics, metals, and glass. The dismantled components including printed circuit boards (PCBs) (Zhou et al., 2016), lithium-ion batteries (LiBs) (Nitta et al., 2015), and display screen (Wang et al., 2015) need further treatment owing to their high integration (Zhang et al., 2015). Aiming at a closed-loop supply chain, the existing recycling and deep recovery process can reclaim the valuable resources (Fig. 1). When the recycled materials are manufactured, hazardous substances including toxic heavy metals (e.g. Pb, Cu) and BFRs can enter into new products, even using formal recycling process. While the new products function, toxic substances are distinctly exposed to public environment and human, which should be not neglected in the whole life cycle of new products (Chen et al., 2016; Song and Li, 2014).

3. Macroscopic-level management for product and component

To minimize the negative impact of public environment and human health, and maximize resource recycling, e-waste legislation has been in

Download English Version:

https://daneshyari.com/en/article/6319384

Download Persian Version:

https://daneshyari.com/article/6319384

Daneshyari.com