Waste Management 33 (2013) 714–721

Contents lists available at SciVerse ScienceDirect

Waste Management

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

A material flow analysis on current electrical and electronic waste disposal from Hong Kong households

Winifred Ka-Yan Lau, Shan-Shan Chung *, Chan Zhang

Department of Biology, Hong Kong Baptist University, Kowloon Tong, Hong Kong

ARTICLE INFO

Article history:
Received 5 April 2012
Accepted 5 September 2012
Available online 6 October 2012

Keywords:
Electronic waste
Material flow analysis
Waste management
Hong Kong

ABSTRACT

A material flow study on five types of household electrical and electronic equipment, namely television, washing machine, air conditioner, refrigerator and personal computer (TWARC) was conducted to assist the Government of Hong Kong to establish an e-waste take-back system. This study is the first systematic attempt on identifying key TWARC waste disposal outlets and trade practices of key parties involved in Hong Kong. Results from two questionnaire surveys, on local households and private e-waste traders, were used to establish the material flow of household TWARC waste. The study revealed that the majority of obsolete TWARC were sold by households to private e-waste collectors and that the current e-waste collection network is efficient and popular with local households. However, about 65,000 tonnes/yr or 80% of household generated TWARC waste are being exported overseas by private e-waste traders, with some believed to be imported into developing countries where crude recycling methods are practiced. Should Hong Kong establish a formal recycling network with tight regulatory control on imports and exports, the potential risks of current e-waste recycling practices on e-waste recycling workers, local residents and the environment can be greatly reduced.

1. Introduction

Electrical and electronic waste, or e-waste, is a generic term for electrical and electronic equipment (EEE) that has come to the end of its useful life. Another commonly used acronym is WEEE, waste electrical and electronic equipment. In the past few decades, treatment of e-waste has become a global waste management challenge owing to the fast obsolescence of modern technologies and the potential environmental and human exposures to hazardous materials during their recycling and disposal (de Oliveira et al., 2012). In addition, the transboundary movement of e-waste from developed countries to developing ones, where they are dumped or improperly managed, causes severe environmental and health problems for decades or centuries to come (Shinkuma and Huong, 2009).

Information on the generation, disposal and flow of e-waste is important for the planning of cost-effective treatment and handling capacity in addition to, estimating the scale and possible consequences of the mishandling of e-waste. Yet accurate information on the material flow of e-waste in an economy is hard to obtain, as it is often the case that secondary and waste products do not appear in national statistics of production, sales and traded-in goods (Nnorom and Osibanjo, 2008). Hong Kong is often mentioned as a transit port through which e-waste travels from developed nations to China for recycling in the informal sector (Information Services Department [ISD], 2009; Puckett et al., 2002; Wong et al., 2007). However, there is a dearth of studies that explores the actual e-waste situation in Hong Kong. Significant amounts of e-waste are generated locally and, in spite of the legislative efforts of the Hong Kong Special Administrative Region (SAR) Government, equally significant amounts are imported and stored temporarily in the rural areas awaiting re-export. In order to provide support to the Hong Kong SAR Government for the forthcoming producer responsibility scheme (PRS) on e-waste controls (see Section 1.1), a material flow study was conducted to trace the flow of e-waste after its disposal by Hong Kong households. This study is the first of its kind in Hong Kong SAR and it is acknowledged that there are still gaps in the information that need to be filled. Nevertheless, the findings are indicative of the current situation and are consistent with similar studies in Mainland China where a similar e-waste recovery process is in place (Liu et al., 2006; Streicher-Porte and Yang, 2007; Yang et al., 2008).

1.1. PRS control on e-waste in Hong Kong

With a growth rate of 2% per year, e-waste is one of the fastest growing components of the municipal solid waste stream in Hong Kong (Environment Bureau, 2010). Chung et al. (2011) estimated that Hong Kong households alone generate approximately 80 thousand tonnes of televisions, washing machines, air-conditioners,

* Corresponding author. Tel.: +852 34117741; fax: +852 34117743.
E-mail address: sschung@hkbu.edu.hk (S.-S. Chung).

0956-053X/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.wasman.2012.09.007

refrigerators, and computers (TWARC) as waste annually. These e-waste figures are likely to continue to increase owing to the proliferation of electronic and electrical devices, falling retail prices and planned obsolescence (de Oliveira et al., 2012) although the final results also depend on the popularity of downgauging designs and multi-functional EEEs.

To tackle the e-waste problem, the Hong Kong Government has proposed a new PRS for the proper disposal of e-waste with priority being given to the treatment of TWARC waste (Environment Bureau, 2010). PRS is an environmental management tool founded on the Extended Producer Responsibility (EPR) notion. EPR is becoming increasingly popular as a theoretical basis for hammering out the management solution for the management of e-waste and has been adopted by many developed countries in the past decade (Ongondo et al., 2011; de Oliveira et al., 2012). The Directive on Waste Electrical and Electronic Equipment in the European Union, the Home Appliance Recycling Law and the Law for the Promotion of Effective Utilisation of Resources in Japan, and the Waste Disposal Act in Taiwan are but a few examples. The Organisation for Economic Co-operation and Development (OECD) (2001) defines EPR as "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product life cycle". By adopting EPR, both the physical and financial responsibilities for end-of-life treatment may be shifted fully or partially to the producers and away from governments and albeit to a lesser extent, may also motivate producers to incorporate environmental initiatives into the design of their products.

Based on overseas experience, the Hong Kong Government estimates that an appropriate level of recycling fees to be charged to consumers would be HK$100–250 for a piece of home appliance and a lower amount for computer products. This fee would be collected at the point of sale and would be used to fund a recycling plant with an annual handling capacity of 30,000 tonnes (Cheung, 2011), although this represents less than 40% of the locally generated TWARC waste from households when compared with the estimation of Chung et al. (2011). In addition to such treatment facilities, effective logistical arrangements for collection of the material will be central to implementing a PRS in Hong Kong, where the majority of residents live in high rise buildings and have limited, if any, storage space in their flats. Collection points must be widely available and highly accessible to consumers as they will need to dispose of e-waste immediately once an item breaks or becomes obsolete, and will require prompt collection and treatment. However, specific details of the scheme are still to be disclosed as no timetable has been agreed for implementation (Cheung, 2011).

According to the Environment Bureau (2010), 80% of e-waste generated in Hong Kong is recycled and the majority of it is sold through second hand dealers to developing countries for recycling. The high volume of e-waste that flows through the existing collection and recycling system demonstrates that this system is highly effective and popular amongst consumers. Although it is known that second hand dealers do play a role in this process, the flow of materials disposed of by consumers through their intricate network remains largely unknown even to the Hong Kong Government.

1.2. Material flow analysis (MFA)

Based on the law of material conservation, a MFA systematically connects the sources, pathways and the intermediate and final sinks of a material (Brunner and Rechberger, 2004; Steubing et al., 2010). The results of a MFA can be controlled by simply comparing all inputs, stocks and outputs of a process, making it an attractive decision-support method tool in resource management (Brunner and Rechberger, 2004). Several studies have used MFA to quantify and trace the flow of particular e-waste categories, including computers and consumer durables (Kang and Schoenung, 2006; Kumar and Shrihari, 2007; Oguchi et al., 2008; Steubing et al., 2010), and to identify networks and chains connecting different phases of the EEE life cycle and the associated stakeholders (Streicher-Porte et al., 2005; Jain and Sareen, 2006).

The first step in conducting a MFA for e-waste in a particular country/region/city is to establish its e-waste inventory. Five methods have been developed to determine the e-waste inventory (UNEP, 2007). The data requirements for each of the methods are summarised in Table 1. Sales data is usually derived from production, import and export statistics while stock data, or the amount of EEE currently in service, can be ascertained from the penetration rates (i.e. percentages of households/workplaces currently containing a particular EEE) or derived from assumptions. The average lifetimes of items on the other hand, are more variable and depend greatly on the behaviour and habits of individual consumers.

1.2.1. Time step method

E-waste calculations made using the time step method are based on the difference between private and industrial stocks between two consecutive years plus the sales in that period (Streicher-Porte, 2006). This method should ideally be applied to saturated markets where each obsolete item is immediately replaced by a similar new one. The method can be mathematically represented for the year t as:

$$\text{E-waste generation }(t) = [\text{stock }(t-1) - \text{stock }(t)] + \text{sales }(t) \quad (1)$$

1.2.2. Market supply method

The market supply method uses data on production and sales. E-waste generation is estimated on the basis of historical production and sale figures by extrapolating backwards over the assumed lifespan of an item. Mathematically, it can be represented as:

$$\text{E-waste generation }(t) = \text{sales }(t-d_n) + \text{reuse }(t-d_s) \quad (2)$$

where d_n is the average lifetime of new items and d_s is the average lifetime of second-hand items.

The market supply method has been widely used to estimate e-waste generation (Streicher-Porte et al., 2005; Jain and Sareen, 2006; Kumar and Shrihari, 2007) because usually, sales data are readily available from market research, trade institutes or official statistics and are of good quality.

1.2.3. Carnegie Mellon method

First developed by Matthews et al. (1997), the Carnegie Mellon Method is a data intensive calculation of e-waste quantities based on historical sales data, typical lifetimes, recycling and storage information. It is a variation of the market supply method but additionally considers the post consumption behaviour of consumers for which there are four options: (1) reuse; (2) storage; (3) recycling and (4) landfill (UNEP, 2007). However, country specific data, such as recycling rates and consumer behaviour and preferences, such as lifespan, in addition to a large volume of historical sales data are needed for the model to be applied. The model incorporates a sophisticated study of a product's end-of-life cycle and is

Table 1
Data requirements for determining e-waste inventory.

Calculation method	Data requirements		
	Sales	Stock	Average lifetime
Time step	✓	✓	
Market supply	✓		✓
Carnegie Mellon	✓		✓
Approximation 1		✓	✓
Approximation 2	✓		