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ScienceDirect
Journal of Cleaner Production 16 (2008) 1046–1061
Journal of Cleaner Production
www.elsevier.com/locate/jclepro

LCA of spent fluorescent lamps in Thailand at various rates of recycling

Witoon Apisitpuvakul [a,*], Pornpote Piumsomboon [b], Daniel J. Watts [a,c], Woranut Koetsinchai [d]

[a] *National Research Center for Environmental and Hazardous Waste Management, Chulalongkorn University, Payathai Road, Bangkok 10330, Thailand*
[b] *Chemical Technology Department, Chulalongkorn University, Bangkok 10330, Thailand*
[c] *Center for Environmental Engineering and Science, New Jersey Institute of Technology, University Heights, Newark, NJ 07102-1982, USA*
[d] *Department of Mathematical Science, King Mongkut's University of Technology Thonburi, Prachauthit, Suksawasd 48, Bangkok 10140, Thailand*

Received 20 October 2006; received in revised form 25 April 2007; accepted 1 June 2007
Available online 4 September 2007

Abstract

This paper presents environmental impact of a fluorescent lamp (a long straight tube 36 watts, 200 g and 13,600 h for mean time before failure) when considering different disposal methods (recycle and non-recycle) of its spent fluorescent lamp (SFL). The study was applied for the case in Thailand using life cycle assessment (LCA) as a tool. All materials, energy use, and pollutant emissions to the environment from each related process were identified and analyzed. Impact assessment was conducted for 10 environmental impact potentials: carcinogens, respiratory organics, respiratory inorganics, climate change, radiation, ozone layer, ecotoxicity, acidification/eutrophication, land use and minerals. The analysis followed Eco-Indicator 99 method, individualist version 2.1. The main focus of the study was to compare the impact of SFL recycling with non-recycling before landfilling. The impact intermittent activities, production of raw material and energy used in all the concerned processes were taken into account. However, transportation activities were excluded. The results showed that for all recycling rates, cement production is the main contributor to the environmental impacts, while sodium sulfide production is second and electrical production, the third. Mercury vapor emission showed a small contribution in carcinogens and ecotoxicity. The impacts are reduced when recycling rate is increased. The reduction of cement consumption in disposal processes or the process improvement of cement production may also help to reduce environmental impacts.

Keywords: Life cycle assessment; Spent fluorescent lamps (SFLs); Disposal; Recycling; Environmental impacts; Eco-indicator 99 method

1. Introduction

End-use product recycling is one approach to waste management that can reduce the burden to the environment, such as reduction in landfill space. Recycling also reduces the consumption of refined materials and energy used (saving resource usage) for new material extraction [1]. It thus helps to improve environmental performance over the life cycle of products and also generate market values for selling recovered materials. Nevertheless, the recycle process itself also consumes materials and energy, starting from end-use product transportation, disassembly at recycling plants, treatment of wastes emitted from these processes and, ultimately, the disposal of residual wastes, respectively. Therefore, before making a decision to recycle, both aspects of saving resources and recovering materials have to be analyzed in order to determine which approach gives the overall benefit

* Corresponding author. Tel./fax: +662 214 1044/218 8132.
E-mail addresses: api_wit@hotmail.com, wit_api@yahoo.com (W. Apisitpuvakul).

0959-6526/$ - see front matter
doi:10.1016/j.jclepro.2007.06.015

to the environment. At the present time, for some end-use products, especially spent fluorescent lamps (SFLs), the study that provides and confirms the amount of environmental impact due to the recycling compared with the landfill, is still lacking.

In order to evaluate these benefits of each end-use product handling, life cycle assessment (LCA) is an appropriate tool in this manner, as it examines the environmental burden generated by a product or process for its entire life [2–8]. It will provide a fair verdict for each approach as all activities in each alternative will be evaluated and all environmental burdens will be taken into account. Materials, energy, and pollutants or waste released are quantified over the whole life cycle from "cradle to grave" [9].

Thus, in this study We employed LCA as an assessment tool to analyze recycling and landfill disposal of SFLs. A long straight tube SFL (36 watts, 200 g and 13,600 h for mean time before failure) was selected as a product model. The system boundary starts at the site where SFLs were transported. Its result would provide the environmental impacts due to the SFLs recycling at different recycling rates (or percent) compared with the landfill and could be used as a guideline for decision makers to decide on SFL disposal facilities.

SFLs are one type of consumer products that can be recycled. As the fluorescent lamps (FLs) contain problematic quantities of a toxic element, mercury, a special technology is required. The FLs are normally either a four- or eight-foot long straight tube or a circular tube. The tube diameters are typically 1 in, 1.5 in, or 2.125 in. Every lamp is labeled with a code containing information in the following order: lamp type (e.g., F = fluorescent), shape (e.g., T = tube, B or U = u-shaped, c = circular), lamp length (e.g., 12″, 24″, or 96″) or nominal wattage (e.g., 40) [10]. The components of FLs are shown in Fig. 1.

The amount of mercury in a FL depends upon type of the lamp as well as the year of manufacture. The mercury content

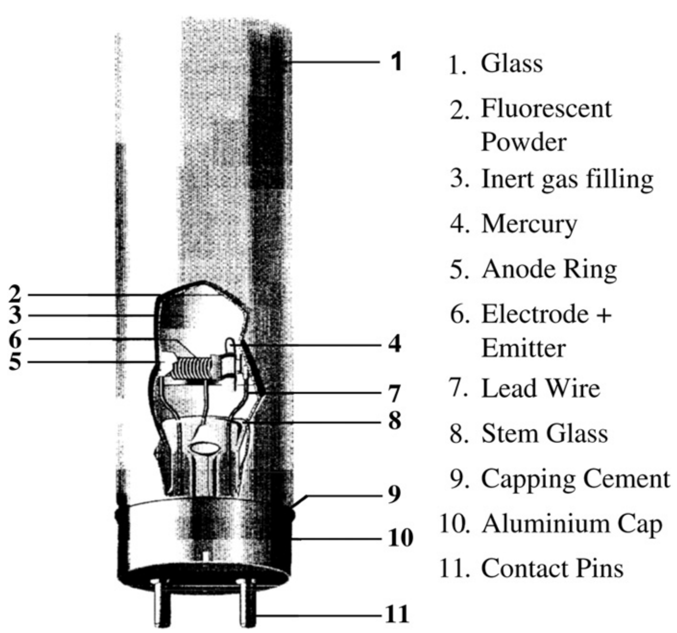

Fig. 1. The components of a fluorescent lamp [11].

in FLs made prior to 1992 was >40 mg in FT12 (1.5-in diameter tube) and >30 mg for FT8 lamps (1-inch diameter tube). By 1997, FL manufacturers reduced this amount to <21 mg for FT12 and <10 mg for FT8 lamps, respectively [12]. Research Triangle Institute estimated mercury emission due to a lamp breakage at about 6.8% of the total mercury content per lamp [12]. Moreover, the National Electric Manufacturers Association [13] estimated that mercury vapor from non-operating lamps ranged from 0.06 to 0.2% of total mercury content. Additionally, NEMA also estimated that mercury emissions from broken lamps were about 1% of total mercury which was much lower than that reported by EPA (1998). Aucott et al. [14] studied the release of mercury from broken fluorescent bulbs. With the assumption that all mercury released as elemental vapor, it was found that between 17% and 40% of the mercury in broken low-mercury fluorescent bulbs was released to the atmosphere during a two-week period immediately after the breakage. At high temperature the releasing rate becomes higher. One-third of the total mercury release would occur during the first 8 h after breakage. Mercury attacks the central nervous system and adversely affects the mouth, gums, and teeth. High exposure over long periods of time will result in brain damage and ultimately death [15]. In the U.S.A., SFLs are classified as a hazardous waste as they exhibit toxicity characteristics (EPA hazardous waste number D009). Therefore, they have been fully regulated under a hazardous waste rule. However, as this regulation is rather strict, EPA announced changes of the hazardous waste rule. Because some of SFLs are not only released from industries but also released from households. Therefore, to classify this kind of waste as only industrial hazardous waste may not be appropriate and adequate. Thus, these changes resulted in classifying the spent FL as a universal waste. The universal waste is low risk hazardous waste generated by a variety of people. This waste has three categories: CRTs, thermostats, batteries and lamps (fluorescent tubes, discharge lamps, mercury vapor lamps, batteries (not auto), and mercury thermostats. This waste must be disposed of properly [12].

In Thailand, fluorescent light tubes are still classified as hazardous materials under the Notification of Ministry of Industry No.6, B.E.2540 [16]. A study of the Pollution Control Department [17] indicated that the quantity of SFLs discarded in Thailand is approximately 45 million lamps per year. The study also suggested that the demand of fluorescent lamps has been growing due to population and economic growth. There are a number of studies concerning the safety of SFLs disposal including both recycling and non-recycling processes. Rabah et al. [18] studied the aluminum, nickel–copper alloy recovery from spent fluorescent lamps. Water containing 35% acetone was used to capture mercury vapor while the spent lamps were decapped. Krivanek [19] reviewed three mercury control technologies: activated carbon injection, sodium sulfide injection, and wet scrubbing for municipal waste combustors (MWCs). It was concluded that these technologies suffered from disadvantages or potential deficiencies as the amount of mercury released from the combustor was still taking place after using these mercury control technologies.