Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 29 (2015) 372 – 377

www.elsevier.com/locate/procedia

The 22nd CIRP conference on Life Cycle Engineering

Leveraging life cycle assessment to evaluate environmental impacts of green cleaning products

Kathryn G. Van Lieshout[a,*], Cindy Bayley[a], Sarah O. Akinlabi[b], Lisa von Rabenau[c], David Dornfeld[a]

[a]*Department of Mechanical Engineering, University of California, Berkeley, CA, 94709, United States*
[b] *Department of Chemical Engineering, University of California, Berkeley, CA, 94720, United States*
[c] *Department of Mechanical and Process Engineering, Technische Universität Darmstadt, 64289 Darmstadt, Germany*

* Corresponding author. *E-mail address:* kvanlieshout@berkeley.edu

Abstract

The green cleaning industry continues to pursue products that reduce or eliminate impacts on human health and the environment; however, these impacts over the life cycle are not well understood. This study assessed environmental impacts of four green cleaning products from Method Products, PBC (all-purpose cleaner, hand wash, dish soap) and Ecover (dish soap). A life cycle assessment from cradle-to-grave was performed using ReCiPe and IPCC GWP methodologies. Results correlated greatest impact contributors to ingredient composition and identified the need to improve data quality. Based on the findings, a prioritized list of actions for green cleaning companies was developed.

Peer-review under responsibility of the scientific committee of The 22nd CIRP conference on Life Cycle Engineering

Keywords: life cycle assessment; cleaning products; ecological footprint; global warming potential; environmental impact

1. Introduction

Among a complex and ever-changing chemical market, the need to understand the impact cleaning products have on our health and environment has become increasingly vital. Global production of chemicals is expected to grow at a rate of 3% each year, significantly faster than the population growth rate. Meanwhile, production, price, and performance drive the U.S. chemical market rather than human health and the environment [1]. To this end, green chemistry aims to design "chemical products and processes [that] reduce or eliminate the use and generation of hazardous substances" [2].

The green cleaning industry has grown through demand by consumers for environmentally-friendly products while maintaining product effectiveness, as well as through pressure by industry regulations. With over 85% of our lives being spent indoors in the United States [3], it is important to address the health hazards of cleaning products. Many cleaning product companies have begun pursuing greener chemicals as they foresee not only social and environmental benefits but economic benefits as well. According to a 2011 report by Pike Research [4], transitioning from petroleum-based chemicals to green chemicals has the potential to save industry $65.5 billion by 2020. Additionally, new regulations soon to be enforced by the European Union require that cleaning products display their Product Environmental Footprint (PEF) on packaging labels [5].

2. Background

Many attempts have been made to understand the health and environmental hazards of green cleaning products, but very few have examined products over their entire life cycle. Current practices frequently focus on human toxicity impacts from using the formulations. To accomplish this, chemicals are often screened by third party companies and resources such as McDonough Braungart Design Chemistry (MDBC), the Pharos Project, or Green Screen. However these do not encompass the full extent of impacts over products' life cycles. Other evaluation methods include Cradle to Cradle, a

Peer-review under responsibility of the scientific committee of The 22nd CIRP conference on Life Cycle Engineering
doi:10.1016/j.procir.2015.02.063

certificate program that rates products in terms of material, energy, water, and social factors [6]. On occasion, companies have developed their own frameworks, such as Ecover's Diamond Model, by which they evaluate all of their products across the entire life cycle [7]. While all these methods aim to quantify environmental impacts, they are limited by having a narrow scope or by not being standardized. Life cycle assessment (LCA) can help fill these gaps to better understand comprehensive environmental impacts of cleaning products.

Previous LCAs of chemical products have been sparse and inconsistent in their methodologies, and few have focused on cleaning products. When examining LCA trends in pharmaceutical and chemical industries, Jiménez-González and Overcash [8] indicated that life cycle inventory (LCI) data is not available for most chemicals. Possibly as a result, many groups have formulated their own methodologies for LCA of chemical products. Yu et al. [9] developed an analytic hierarchy process that resulted in a single score environmental metric, while Saouter et al. [10] used risk quotients (a function of consumption, removal, sewage flow, and dilution).

There are a few existing studies that use LCA to evaluate the environmental impacts of cleaning products. An existing comparative LCA study by Kapur et al. [11] demonstrated that general purpose cleaning products compliant to the Green Seal Standard for Cleaning Products for Industrial and Institutional Use, GS-37, had substantially lower environmental impacts than conventional cleaning products in the market. Kuta et al. [12] performed a LCI of two hard surface cleaning products from Procter & Gamble (P&G) in order to "develop baseline information on the relative contribution of various ingredients, processes, and consumer use and disposal to total resource use and emissions." The authors of this paper argue that "the true value of LCI is the realization that a change in one portion of a product's life cycle will have some effect (either positive or negative) in other areas of the product's life cycle. By applying this 'life cycle thinking' to the product design process, true improvement opportunities can be identified" [12]. Saouter and van Hoof [13] used SimaPro to construct a LCI database for examining P&G laundry detergents. With this database and CML92 methodology, they performed a life cycle impact assessment (LCIA) from cradle-to-grave of a hypothetical laundry detergent used in Belgium excluding transportation. This study maintains that "LCIA is the appropriate tool to help determine to what extent a particular product, process or ingredient's emissions may be associated with a particular impact category" [13].

Compared to conventional cleaning products, green cleaning products already have reduced health and environmental impacts, yet the impacts over the life cycle remain to be understood. The purpose of this investigation is to evaluate life cycle environmental impacts of several green cleaning products in order to identify opportunities for improvement within product formulations and across product life cycles. Method Products, PBC can in turn use these guidelines to further reduce environmental and health impacts. This study demonstrates how through a comprehensive analysis, a prioritized list of actions for green cleaning companies can be developed in order to augment their current methods of creating environmentally-friendly products.

3. Methodology

Environmental impacts were determined by means of a life cycle assessment (LCA), following ISO 14040 guidelines through the process of: goal and scope definition, inventory analysis, impact assessment, and interpretation [14]. Products were analyzed from cradle-to-grave, which is defined as considering the impacts from raw material extraction through production and use to disposal. Fig. 1 delineates the specific phases of the life cycle that were included in this analysis. System Boundary 1 considers the ingredients within each product formulation and System Boundary 2 assesses impacts based on life cycle stages (product formulation, use, transportation, and end-of-life). It is important to note that packaging was excluded from the analysis, as both companies have already performed detailed LCAs on their packaging.

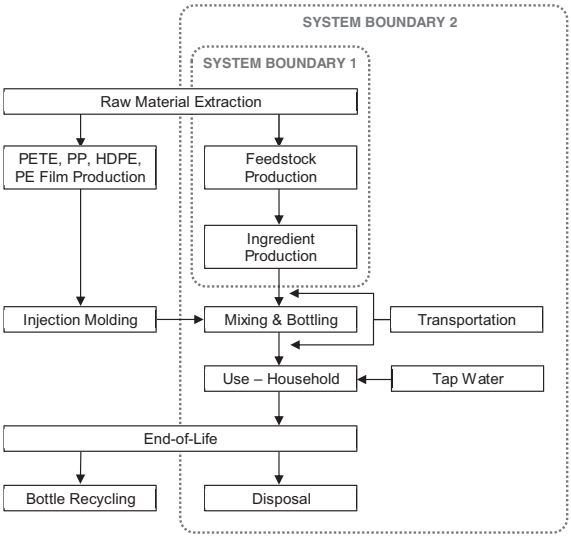

Fig. 1. Simplified system boundary diagram for evaluated products.

The analysis was conducted using LCA software SimaPro 8 [15] with the ecoinvent v3 database [16]. Analysis methodologies included IPCC GWP 100a [17] and ReCiPe Endpoint H [18] to determine global warming potential (GWP) and categorical environmental impacts, respectively. The 18 impact categories included in ReCiPe are: climate change, ozone depletion, terrestrial acidification, freshwater eutrophication, marine eutrophication, human toxicity, photochemical oxidant formation, particulate matter formation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, ionizing radiation, agricultural land occupation, urban land occupation, natural land transformation, water depletion, metal depletion, and fossil depletion. European E/A normalization factors in ReCiPe were applied to impact categories to achieve a single score evaluation represented as "millipoints."

The selected methodologies provide comprehensive representations of environmental impacts and communicable results. The ReCiPe methodology offers a "harmonized" set of modeling principles and the middle-ground, hierarchist (H) perspective represents "the most common policy principles