Environmental Impact Assessment Review 62 (2017) 35–48

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

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

Analytical method of waste allocation in waste management systems: Concept, method and case study

Francis C. Bergeron

Institute for Environmental Sciences, University of Geneva, Uni Carl Vogt, Boulevard Carl-Vogt 66, CH-1205 Geneva, Geneva, Switzerland

ARTICLE INFO

Article history:
Received 26 February 2016
Received in revised form 14 June 2016
Accepted 7 October 2016
Available online xxxx

Keywords:
Waste management system
Material Flow Analysis
Waste allocation
Household solid waste
Case study
Geneva/Switzerland

ABSTRACT

Waste is not a rejected item to dispose anymore but increasingly a secondary resource to exploit, influencing waste allocation among treatment operations in a waste management (WM) system. The aim of this methodological paper is to present a new method for the assessment of the WM system, the "analytical method of the waste allocation process" (AMWAP), based on the concept of the "waste allocation process" defined as the aggregation of all processes of apportioning waste among alternative waste treatment operations inside or outside the spatial borders of a WM system. AMWAP contains a conceptual framework and an analytical approach. The conceptual framework includes, firstly, a descriptive model that focuses on the description and classification of the WM system. It includes, secondly, an explanatory model that serves to explain and to predict the operation of the WM system. The analytical approach consists of a step-by-step analysis for the empirical implementation of the conceptual framework. With its multiple purposes, AMWAP provides an innovative and objective modular method to analyse a WM system which may be integrated in the framework of impact assessment methods and environmental systems analysis tools. Its originality comes from the interdisciplinary analysis of the WAP and to develop the conceptual framework. AMWAP is applied in the framework of an illustrative case study on the household WM system of Geneva (Switzerland). It demonstrates that this method provides an in-depth and contextual knowledge of WM.

1. Background

The connotation of waste was initially and commonly negative (Dijkema et al., 2000). The term "waste" comes from the Latin word *vastus* that means unoccupied or desolate (Kennedy, 2012). However, this notion remains intrinsically subjective (Pocklington, 2003) and loaded with value judgements (Grathwohl, 1978) because waste does not constitute an intrinsic propriety of an item but a perception of it given by its owner (Christensen, 2011; Hird, 2012). From the point of views of production theory and the economy, waste initially represents an "intermediate commodity" (Koopmans and Koopmans, 1951), an "undesired commodity" (Schmidt, 2005) or a "*rejectanea*" (Jevons, 1871). It also constitutes an unwanted by-product or object with a zero or negative economic value (Daly and Farley, 2010; Porter, 2002; Schmidt, 2005; Vaughn, 2011), thus impacting the way it is managed. Seadon (2010) summarises traditional waste management (WM) as management by "flame, flush or fling". These end-of-pipe waste treatment operations, i.e., disposal operations, simply reflect the dominant model of linear industrial systems from the time of the industrial revolution based on a cradle-to-grave management of resources (O'Lear, 2010). However, alternative waste treatment operations have progressively been substituted for these end-of-pipe treatment operations in recent decades. This has been driven by new environmental regulations, resource and land scarcity and waste policy implementation based on a waste hierarchy and/or resource conservation. These alternative operations based on waste recovery, i.e., recovery operations, have lead to a closed-cycle management of matter and the substitution of natural resources. WM currently includes both disposal and recovery operations at the global level, although to differing degrees (Hoornweg and Bhada-Tata, 2012; Massarutto, 2015; UNEP, 2015). Therefore, waste does not constitute only an externality of production and consumption activities anymore (Chalmin and Gaillochet, 2009; Porter, 2002) and is not regarded as a problematic matter (Knoepfel et al., 2010), which must disposed to minimise its nuisance in terms of the environment and public health. It can also constitute a secondary resource to exploit in order to support resource conservation.

The increased economic value of waste has led to a change from a market of waste disposal with a negative exchange value towards a market of resource recovery with a positive exchange value (Chalmin and Gaillochet, 2009), therefore modifying the function of WM systems within the industrial system. Because waste also forms an input for production (Bertolini, 2006; van Beukering et al., 2014), the WM system no longer represents the final outlet of consumption and production

---

E-mail address: francis.b.c@videotron.ca.

http://dx.doi.org/10.1016/j.eiar.2016.10.001

systems. It has also become one of the supply systems within the production system through waste recovery technologies and operations. Thus, it constitutes both the core of the circular economy (Pinjing et al., 2013) and the "mainstay" of raw material supply for the industrial system in the framework of resource efficiency (Müller, 2013). It continues to form the main interface between the anthroposphere and the environment (Brunner and Bogucka, 2006). Moreover, waste recovery technologies and operations play a key role in the development of urban mining (Brunner, 2011; Cossu, 2013). They also represent a strategy supported by industrial ecology to promote the implementation of an ideal and mature industrial ecosystem (Erkman, 2004). However, these resource management strategies call for efficient waste allocation among appropriate waste recovery operations. In the materials cycle of an industrial economy, this allocation of material occurs during a process that is called "recapture decision" by Rogich and Matos (2002). It separates the usable material fractions of waste, the "garbojunk" (Georgescu-Roegen, 2006), for subsequent reorientation as input into the system of production. In the model of double-layer closed loops, Dyckhoff et al. (2013) denominate this allocation process as the "induction phase". This phase leads to the allocation of waste flows to their original production system as secondary raw materials in an external economic system or their discharge into the environment. This induction phase process is connected to an economic transaction process between a disposer, i.e., one who gives or sells waste, and a provider, i.e., one who takes up or buys this waste. While previous authors (Dyckhoff et al., 2013; Rogich and Matos, 2002) have proposed a relevant conceptual framework to describe and understand this process of waste allocation, their respective framework does not include a methodological approach to assess waste allocation in the WM system.

According to Zurbrügg et al. (2014), the assessment phase forms a fundamental step to obtain a complete and clear knowledge of the WM system, requiring different methods to evaluate existing situations. Material system analysis methodologies (Moll and Fernia, 2005; OECD, 2008), including the Material Flow Analysis (MFA) method (Baccini and Brunner, 1991, 2012; Brunner and Rechberger, 2004), constitute relevant quantitative approaches to study the waste allocation among waste treatment operations in a WM system. They would allow addressing the question of how much waste is recovered or disposed. Moreover, they provide a comprehensive overview of the system's material cycle by a meso-level analysis, giving an adequately detailed analysis for tracking and mapping the circulation of waste flows through and out of a WM system (OECD, 2008). However, they fail to explain this waste allocation, which results from various causal factors (Meylan et al., 2013; Wang et al., 2008). Therefore, the present paper aims to fill this methodological gap through a new method for the qualitative and quantitative analysis of the WM system.

2. Aims and interdisciplinarity

In view of the issues described above, the aim of this study is to address the phenomenon of waste allocation among waste treatment operations by proposing a new method for the analysis of WM. In this sense, this paper introduces the concept of the "waste allocation process" as an innovative research approach for the WM system. The novelty of the proposed method is to use the concept of policy resources from public policy and environmental policy analysis (Klok, 1995; Knoepfel et al., 2010, 2011) to explain the function of the WM system previously described through material system analysis. Therefore, this paper presents a new method for the study of WM for the purposes of description, classification, explanation and prediction, the "analytical method of the waste allocation process" (AMWAP).

This assessment method follows a structural interdisciplinary perspective, which expresses a conceptual and theoretical realignment that gives rise to a new integrated reference frame (Rege Colet, 2002). It uses, for example, concepts and methods from ecological economy (Daly and Farley, 2010), policy analysis (Klok, 1995; Knoepfel et al., 2010), psychology (Friedenberg and Silverman, 2006), the monitoring and evaluation system of conservation biology (Stem et al., 2005) and the MFA methodology (Baccini and Brunner, 2012; Brunner and Rechberger, 2004). Regarding the latter, this study does not use the methodology of Baccini, Brunner and Rechberger in its strict sense. For reasons of simplicity, this study follows the material flow modelling proposed by Meylan et al. (2013) and that of Matsubae-Yokoyama et al. (2009). Nevertheless, the terminology adopted in this study falls under the MFA methodology to the extent possible.

In accordance with the aims and scope of the journal, this paper mainly wishes to describe the theoretical and methodological components of this innovative analytical method. It also provides a comprehensive and reproducible procedure for professionals, experts and academics, including an illustrative case study. Therefore, the structure of this study is as follows. Section 3 presents AMWAP. In Section 4, an illustrative case study presents its implementation through an analysis of household WM in the Canton of Geneva, Switzerland. Section 5 discusses on the originality of the AMWAP, its applicability for professionals, experts and academics and its potential integration in the framework of impact assessment methods. Section 6 presents the mains conclusions of this article.

3. Method

3.1. Purposes and components

AMWAP basically consists of a status assessment. Its purpose is to measure "a set of indicators that give a general picture of a situation at one point in time or over various points in time" (Stem et al., 2005, pp. 303–304). This purely descriptive monitoring and evaluation approach is required because professionals and experts need to measure and to understand what they manage. However, AMWAP is not limited to describing the functioning of a WM system. It may also order, explain and predict it.

AMWAP includes the two necessary components of a monitoring and an evaluation system (Stem et al., 2005): a conceptual framework and an evaluation approach referenced here as an analytical approach. Firstly, it has a conceptual framework giving a "representation of cause-and-effect relationships in a generic fashion [and] provides a generalised representation of reality used to develop specific conceptual models" (Stem et al., 2005, p. 306). Secondly, it includes an evaluation approach refereed to here as an analytical approach, i.e., a step-by-step process to implement AMWAP. In addition, it follows the recommendations of Allesch and Brunner (2014). It follows a goal-oriented analysis, which focuses on two effects of waste policy: the adopted methods of waste treatment in a WM system and the exchanges of waste among systems. It applies the mass balance principle. It includes a transparent and reproducible presentation of the methodology.

3.2. The conceptual framework of WAP

3.2.1. Functions of the conceptual framework

The functions of the conceptual framework are to clarify the concepts and to illustrate their relationships as placed in a logical design. This framework includes three components as illustrated by Fig. 1: the conceptual foundations, the descriptive model and the explanatory model. Firstly, the theoretical foundations constitute the frame of reference for the conceptual framework. They guide the entire process of research study by addressing the phenomenon of waste allocation among waste treatment operations through the concept of the "waste allocation process" (WAP). As illustrated by circle 1 of Fig. 1, the WAP is defined as a "black box" (Wiener, 1961) and constitutes the base of the conceptual framework. The conceptual foundations lead to the definition of the descriptive and explanatory models. Secondly, the descriptive model serves to faithfully represent the operation of WAP by focusing on the observation of input and output flows as illustrated by