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A general methodology for calculating the MSW management self-sufficiency indicator: Application to the wider Barcelona area

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ABSTRACT

In this paper, a new methodology adequate for the separate accounting and analysis of municipal solid waste (MSW) flows of a system is developed, employing the monitoring of these through a metabolic perspective and based on the established MFA methodological guidelines, as proposed by Eurostat in 2001. Additionally, a new indicator is proposed, suitable for the revision of MSW management plans, when combined with the metabolic picture of a system, in line with basic waste management principles. The value of the MSW management self-sufficiency indicator reflects the capacity of a system to manage the amount of MSW it accepts and the grade of sustainability of the treatment practices followed within the system, valuing as the best option the use of residues as raw materials. Compared with waste recovery rates, the new indicator proves to be more comprehensive in assessing the effectiveness of MSW management plans in medium-scale urban regions, evaluating the capacity of a socioeconomic system to close its material circles. In combination with information provided by other urban sustainability indicators, as water use and air pollution, the indicator can be a useful tool in decision making. In this paper, the case of a highly urbanised coastal Mediterranean area (the city of Barcelona and its surroundings) is studied and assessed for a time period of eight years.

1. Introduction

In the context of industrial ecology, researchers view modern industrial economies as living organisms that ‘ingest’ raw materials and energy (always in a constant exchange with the natural environment) which are ‘metabolised’ to produce goods and services, and they ‘excrete’ wastes in the form of discarded materials and pollution (Matthews et al., 2000). In the same lines, a socioeconomic system is considered analogue to natural ecosystems; the difference in this analogy lies in the linearity of socioeconomic systems’ material flows, unlike nature’s closed loops material circles. The linearity of material flows, through the discharge of used materials to the environment as residues, is one of the most profound problems cities are up against, in terms of sustainability; the analysis of a city’s socioeconomic metabolism can help spotting unsustainable practices in its use of natural resources and closing its material circles.

Material Flow Accounting (MFA) is a method for the quantification and the monitoring of the evolution of a society’s metabolism. According to its methodological principles, inputs can either be added to an economy as socioeconomic stocks, or they can end up as outputs of socioeconomic metabolism (Haberl et al., 2004). Therefore, the final amount of outputs is ultimately determined by the magnitude of the inputs. The monitoring of the output flows of a socioeconomic system can help evaluate the course of dematerialisation; as this is directed towards the reduction of primary inputs into an economy (Bringezu and Moriguchi, 2002), the reduction of waste disposal can be considered an indicator of dematerialisation as well. According to Friege (1997), data on waste streams and statistical inquiries into material flows must be standardised and combined. The amount of waste produced can also be seen as an indicator of a society’s efficiency, particularly in relation to the use of natural resources and waste treatment operations (EEA, 2005). Finally, the study of waste as the output flows in a society’s metabolism can provide useful information on waste generation, import and export flows, energy recovery and recycling rates, as well as on the depletion of raw materials (AWAST Project, 2003).

A wide range of indicators has been proposed so far for the assessment of municipal solid waste (MSW) management; the majority is essentially basic and one-dimensional quantitative statements that focus on MSW generation rates and prevalence of treatment and disposal options (Danish EPA, 2003). Typical exam-

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ples of generation indicators are the total and per sector (e.g. household and commercial) annual MSW generation rates, either expressed in totals or per capita values. The amounts of MSW that is landfilled, incinerated or recycled, either in absolute values or percentiles are the most common waste management related indicators, while the landfilling of biodegradable waste and the recycling of packaging waste rates are also monitored by the European Environmental Agency (EEA, 2007). Eurostat, the Statistical Office of the European Communities, uses the abovementioned generation and management indicators and complements them with data on the number, total area and remaining capacity of available waste recovery and disposal installations (Eurostat, 2004a, 2007). Similar indicators are proposed and used by the Organisation for Economic Co-operation and Development (OECD, 2004) and the UN Commission on Sustainable Development (UNCSD, 2001) among others.

Some institutions, such as the Danish Environmental Protection Agency, recognise the variety of environmental issues linked to waste management and the need for the establishment of new indicators based on a Life Cycle Analysis (LCA) perspective (Danish EPA, 2003). These take into account energy and resource consumption and concerns on a global, regional and local level (e.g. global warming, acidification/eutrophication and ozone depletion respectively). MSW management plan evaluations using the LCA approach include the case studies of the Bologna district in Italy (Buttol et al., 2007), the city of Ankara in Turkey (Özeler et al., 2006) and the Basque region of Gipuzkoa (Muñoz et al., 2004).

In terms of urban sustainability, MSW management is a multifaceted subject and problems associated to it are not restricted to the issues of waste minimisation, resource conservation or the application of the best treatment technique. Special importance is given to the social and political aspects of waste management (Furuseth and O'Callaghan, 1991; Hsu, 2006; Joos et al., 1999; Pol et al., 2005; Reams and Templet, 1995).

Local, regional or national plans on waste management handle municipal solid waste, industrial solid waste, municipal and industrial wastewater and air emissions separately. Similarly, this study is focused exclusively on the MSW flows of a system, aiming to evaluate the corresponding management plans and policies. Our objective is to complement the existing quantitative statements related to waste management with an indicator that allows the revision of a MSW management plan in line with basic waste management principles, derived from the theory of social metabolism. Based on the problematic of the material flows' linearity in socioeconomic systems, the suggested indicator assesses a system's capacity for closing its material circles through the material recovery of the MSW this generates. The indicator proposed in this paper can provide useful information on the sustainability of MSW strategies, as it assesses two important aspects of sustainability for any given socioeconomic system: the self-sufficiency in waste treatment[1] and disposal and the closing of its material loops. Furthermore, we intend to assess the carrying capacity of a social system in terms of MSW treatment, by which we mean the amount of waste that this is capable of accepting, not only in technical terms but in terms of social equity as well.[2]

A general methodology for calculating the MSW management self-sufficiency indicator is proposed and then applied on 27 municipalities of Barcelona's Metropolitan Region, in Spain. This is a densely populated coastal zone, highly intensive in terms of industrial, commercial and tourist activities, which we consider to be a representative sample of a developed European urban region.

2. Methodology

The methodological platform of this work is MFA; using some of its main methodological concepts, as the input and output flows and the definition of the system's limits, a new methodology is developed to investigate some aspects of MSW management. MFA is an instrument for the macro-analysis of a socioeconomic system, examining it as a black box; the suggested methodology is a tool for analysing a system on a lower level, in terms of MSW management, taking into account the function of the MSW treatment plants included in the system under study. At this level of analysis we propose a new indicator that assesses in more detail the effectiveness of a MSW management plan.

In the MFA methodology (Eurostat, 2001) there are three gateway flows for Domestic Processed Output (DPO) or Total Domestic Output (TDO) that is air, water and land. We choose in this study to follow the solid flows of a MSW management plan and focus on the way these are managed and the sustainability of these practices. The methodology follows the municipal solid waste flows generated in a system and the secondary waste flows occurring during their treatment.

As the methodology proposed is based on an accounting of municipal solid waste flows in terms of weight, air emissions and water flows generated by a socioeconomic system are omitted as they are of several magnitudes smaller or larger, respectively, than the studied flows. Consequently, either municipal or industrial wastewater generated in a system is not a focal point for this study. However, flows of wastewater generated in MSW treatment plants are relevant as they are generated during the treatment of MSW flows. In other words, their weights are considered because they form part, as outputs, of the MSW management plan that is under evaluation.

2.1. Definition of system limits

The indicator proposed is developed for urban systems of micro- to meso- scale, ranging from municipalities to metropolitan areas. For matters of data availability, the system boundaries must correspond with current administrative regions. In line with the Eurostat methodological guidelines (Eurostat, 2001), we define the system boundaries by the political borders that determine material flows to and from other economies (imports and exports).

A system diagram is given in Fig. 1, displaying all internal and external flows. Of all air emissions and liquid and solid waste generated during all the processes that maintain a socioeconomic system, only municipal solid waste is taken into account (G). This can either be treated in plants inside (I_{dom}) or outside (I_{exp}) the system, be landfilled (I_{landf}) or directly used as raw material (R) after separate collection without previous treatment, either inside or outside the system. The latter includes waste that can be reused and the fractions of separately collected materials that have a market value and are used as prime materials without previous treatment; typical examples are metals, glass and paper.

The system input flows included in the weight balance consist of all the solid municipal waste flows this receives to be treated in its plants (I_{imp}). Input flows not accounted for include imported liquid waste flows to be treated in the system, externally generated air emissions and waste deposited within its limits without previous treatment. System outputs taken into account consist of the municipal solid waste directly sent to be treated in external plants (I_{exp}) and the solid and liquid secondary waste flows generated in

[1] As stated in the Directive 2008/98/EC of the European Parliament and of the Council on Waste (European Commission, 2008).

[2] The term 'carrying capacity' in this work exclusively refers to the capacity of a socioeconomic system to manage and recycle, within its limits, the MSW this generates. There is absolutely no intention of identifying the carrying capacity of a system with its MSW treatment capacity. We do, however, consider the latter as one of the dimensions of 'carrying capacity'.