Local Environment: The International Journal of Justice and Sustainability
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/cloe20

Metabolisms of injustice: municipal solid-waste management and environmental equity in Barcelona's Metropolitan Region

Maria Christina Fragkou [a] , Luis Salinas Roca [b] , Josep Espluga [b] & Xavier Gabarrell [c]

[a] Department of Geography, Faculty of Architecture and Urbanism , University of Chile , Portugal 84, Santiago , 8331051 , Chile

[b] Department of Sociology , Universitat Autònoma de Barcelona , Campus de la UAB, Bellaterra (Cerdanyola del Vallès), 08193 , Spain

[c] Department of Chemical Engineering , Universitat Autònoma de Barcelona , Edifici C, Campus de la UAB, Bellaterra (Cerdanyola del Vallès), 08193 , Spain

Published online: 07 May 2013.

Local Environment, 2013
http://dx.doi.org/10.1080/13549839.2013.792045

Metabolisms of injustice: municipal solid-waste management and environmental equity in Barcelona's Metropolitan Region

Maria Christina Fragkou[a]*, Luis Salinas Roca[b], Josep Espluga[b] and Xavier Gabarrell[c]

[a]*Department of Geography, Faculty of Architecture and Urbanism, University of Chile, Portugal 84, Santiago 8331051, Chile;* [b]*Department of Sociology, Universitat Autònoma de Barcelona, Campus de la UAB, Bellaterra (Cerdanyola del Vallès) 08193, Spain;* [c]*Department of Chemical Engineering, Universitat Autònoma de Barcelona, Edifici C, Campus de la UAB, Bellaterra (Cerdanyola del Vallès) 08193, Spain*

Environmental justice studies that focus on the management of municipal solid waste (MSW) typically examine the unequal distribution of associated health and environmental risks in minority social groups and the political processes that generate these inequalities. With the aim to complement current views on the field, in this work, we explore whether there is an issue of environmental justice in municipal systems' grade of self-sufficiency in treating the MSW that they generate and in their effort to close their material cycles. The methodology used is based on the concept of urban metabolism and is applied to 12 coastal municipalities of Barcelona's Metropolitan Region in Spain. The metabolism of the MSW flows of each system is analysed to examine (i) the system's efficiency to close its MSW cycles, corresponding to an indicator of environmental sustainability, and (ii) the MSW export and import flows, as an indicator of social sustainability. The results demonstrate a positive correlation between socioeconomic status and the externalisation of MSW treatment-related hazards. The proposed indicator proves to be an excellent tool for the evaluation of both the environmental and social performance of a system considering MSW management.

Keywords: municipal solid-waste management; environmental justice; social metabolism; urban sustainability; Barcelona Metropolitan Region

1. Introduction

In the course of the last 40 years, we have witnessed a paradigm shift in solid-waste management practices and targets, following increased public-health concerns and awareness of the environmental issues related to the conservation and efficient use of natural resources. The advances were not restricted to the field of biophysical sustainability, manifested with a transition from end-of-pipe to integrated and preventive management solutions; on the social side of the issue, equity discourses, predominantly related to hazardous-facilities allocation, have evolved from a "not-in-my-backyard" attitude (Furuseth and O'Callaghan 1991) to a "not-in-anyone's-backyard" approach (Bullard 1993), seeking the institutionalisation of *sustainable and just environmental practices that meet human needs without sacrificing the land's ecological integrity* (Bullard 1993). In this paper, we will analyse a win-win framework for MSW management that merges its social and biophysical

*Corresponding author. Email: mariac.fragkou@gmail.com

aspects, based on the minimisation of MSW exports on the municipal level through the complete material recovery of MSW at the local scale.

In the urban context, municipal solid waste (MSW) treatment and disposal is a subject of high complexity, the social dimension of which has increased in importance for local authorities, communities and decision-makers (Petts 1994, Joos *et al*. 1999, Hsu 2006). Equity issues in MSW management have been principally studied using the environmental justice concept (for example, see Hofrichter 1993, Curtice *et al*. 2005, US EPA 2008). The first social concerns of MSW primarily involved the spatial and social distribution of MSW-treatment hazards, given that related facilities are associated with local health and environmental risks, such as soil contamination, air pollution and loss of clean water courses, among others (US EPA 1992). Extended literature has demonstrated that areas inhabited by disadvantaged social groups tend to host these types of facilities, involving issues of environmental injustice (Schnaiberg 1980, Beck 1992, Schnaiberg *et al*. 1998, Futrell 2000, Hunter *et al*. 2003, Ringquist 2005).

However, environmental justice studies related to waste treatment have broadened their view and have become more holistic in scope since the first paradigms of environmental racism were aroused in the 1980s in the USA, dealing with the siting of polluting facilities in areas predominantly inhabited by racial minorities (GAO 1983, Bullard 1994). Robert Bullard distinguishes three types, or dimensions, of environmental justice, namely procedural, geographical and social (Bullard 2005), which cover all aspects of environmental inequities. The majority of environmental justice studies since then have been developed and advanced based on these three dimensions, interpreting the background of each problem and elaborating on the issue.

Relevant literature on MSW demonstrates how procedural inequities result in unequal distribution of environmental risks and services on the basis of race, gender and economic status (Krueger and Agyeman 2005). Regarding the political component, scholars have detected unequal enforcement of environmental laws and policies (Konisky 2008) and limited participation or representation of minority and low-income groups in environmental issues (Pulido 1996), identified more concretely during decision- and policy-making processes that determine the siting of hazardous materials and polluting industries (Faber 1998 in Krueger and Agyeman 2005). With regard to the results of these processes, authors focus on the selective siting of polluting facilities in territories of minority and low-income groups (Carr 1995, Ringquist 1997, Pastor *et al*. 2002) as well as the poor access of the latter to environmental services and good environmental quality compared to that of higher-class communities (OECD Environmental Directorate 2004, Macintyre *et al*. 2008).

The above-mentioned environmental justice concerns and research lines are accurately summarised in the principles set in the People of Colour Environmental Leadership Summit (Bullard 2005) that state, among others, that (i) there must be an equitable social and regional distribution of negative environmental impacts, and (ii) resources and environmental services should be allocated and distributed equally to ensure the survival of all of the individuals of the population that depend on these resources and services.

The application of these declarations to the subject of MSW would correspondingly require (i) a just social and geographical distribution of related treatment and disposal facilities and (ii) comparable MSW-management practices among communities, capable of ensuring the *survival of all individuals*. In terms of natural resource conservation, the latter would also require the reduction of the waste to be disposed through the maximisation of reuse and recycling.

To reach these goals, it is necessary to begin with an effective MSW-management scheme, basically implemented on the municipal level. Management plans are responsible for the collection, separation and treatment of generated waste, and they can influence the habits of citizens with regard to waste generation and separation at the source. Yet, to the authors' knowledge, there are no studies of the environmental and social equity dimensions of MSW-management plans in the international literature. Typical municipal MSW management-assessment plans use indicators of waste recovery, energy consumption and environmental and health impacts (for example, see Massoud *et al*. 2003, Iriarte *et al*. 2009, Rives *et al*. 2010). However, the externalities associated with the waste exported to other municipalities for treatment or final deposition are not taken directly into account, omitting another environmental justice dimension of MSW management.

Based on these observations and with the aim to complement current views on environmental justice and MSW management, in this work, we propose a framework for the analysis of the environmental equity of existing MSW-management plans, considering the amounts of exported waste. We argue that a system that is self-sufficient in MSW treatment and/or closes its material loops is not only sustainable in ecological terms but is socially sustainable as well because it does not externalise the hazards associated with the treatment and disposal of its waste, through the minimisation of exported waste. In this manner, we seek a correlation between environmental justice and biophysical sustainability in the field of MSW management, coupling qualitative and quantitative expressions of sustainability.

The MSW management-plan analysis is achieved through the separate accounting of a system's MSW flows based on the established material flow accounting (MFA) methodological guidelines, as proposed by Eurostat (2001). The methodology monitors through a metabolic perspective the MSW input and output flows of a given system (imported and exported waste, respectively) and the secondary waste flows occurring during their treatment until their final sink.

A MSW-management self-sufficiency indicator is derived from the metabolic analysis, the value of which reflects (i) the capacity of a system to manage the amount of MSW that it accepts (i.e. its self-sufficiency in waste treatment and disposal) and (ii) the grade of sustainability of the treatment practices followed within the system, valuing as the best option the use of residues as raw materials (i.e. the system's capacity for closing the material cycles through the recovery of the MSW that it generates). Our hypothesis is that the indicator assesses the MSW-treatment carrying capacity of a social system not only in technical terms, but also in terms of social equity.

The MSW-management self-sufficiency indicator is applied to 12 coastal municipalities situated in Barcelona's Metropolitan Region, in Catalonia, Spain. The results are compared to a series of socioeconomic indicators that help us categorise the studied systems in terms of social class. Our aim is to explore how socioeconomic conditions correlate to the performance of the MSW-management self-sufficiency indicator. In other words, we seek to explore whether there is an issue of environmental justice in the grade of self-sufficiency of the social regarding the treatment of the MSW that they generate and in their effort to close their material cycles.

In the following sections, the socioeconomic parameters employed to characterise the municipalities are presented, and the methodology for the calculation of the MSW self-sufficiency indicator is outlined. Furthermore, the waste-management policy of the wider region that hosts the studied municipalities is analysed. The results of the waste indicator and social class characterisation are presented separately and then compared. Finally, the key findings are discussed, and the conclusions of the study are presented.

2. Presentation of the MSW-management self-sufficiency indicator

2.1 Methodological framework

According to the theory of social metabolism (Fischer-Kowalski 1998), the constant throughput of materials and energy in socioeconomic systems is analogous to the metabolic process of natural systems and organisms. In this context, raw materials, water and air are extracted from nature as inputs to the system, which are then transformed into products and finally re-transferred to the natural system as outputs (wastes and emissions). Based on the problem of the linearity of socioeconomic systems' material flows, unlike nature's closed-loop material cycles, Fragkou *et al*. (2010) developed a methodology for the accounting and analysis of MSW flows. The methodological tool employed for the analysis of social metabolism is MFA (Eurostat 2001). Using some key MFA methodological concepts (namely the input, output and secondary flows and the definition of the system's limits), the developed methodology monitors based on a metabolic perspective the MSW input and output flows of a given system, and the corresponding secondary waste flows occurring during treatment, until their final sink.

The methodology has been developed for urban systems from the micro- to meso-level, ranging from municipalities to Metropolitan areas. For matters of data availability, the system boundaries must correspond with current administrative regions. In accordance with the Eurostat (2001) methodological guidelines, the system boundaries are defined by the political borders that determine material flows to and from other economies (imports and exports).

In this work, we choose the municipal level as a unit of analysis for both political and practical reasons. First, although MSW legislation is normally regulated on supranational and national levels, its implementation is under the jurisdiction of smaller administrative units, such as counties and municipalities, and the final success of the legislation depends on the political will of local authorities. Lessons from waste-prevention initiatives extend this idea because these initiatives are more easily implemented in small towns and municipalities (Alió 2008). Moreover, the municipal level is also convenient for reasons of data availability because most national statistical databases provide MSW-related data per city. These arguments do not exclude the analysis of larger-scale systems on the sub-national level, the study of which can provide important evidence on environmental justice issues from a different perspective, as similar multi-scale studies of waste management have revealed (D'Alisa *et al.* 2012).

A system diagram is given in Figure 1, displaying all of the internal and external flows of a given system. Of all of the air emissions and liquid and solid waste generated during all of the processes that maintain a socioeconomic system, only the MSW is taken into account (G). This waste stream can either be treated in facilities inside (I_{dom}) or outside (I_{exp}) of the system, be landfilled (I_{landf}) or be directly used as raw material (R) after separate collection without previous treatment, either inside or outside the system. The latter material 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 metal, glass and paper.

The system's input flows included in the weight balance consist of all of the MSW flows that the system receives for treatment in its facilities, including those generated by other socioeconomic systems (I_{imp}). This category does not include the landfilled waste within the system's limits because landfills are considered to be outside the limits of a socioeconomic system regardless of their position with reference to the landfill.[1] As a consequence, landfilled waste is always regarded as an export, and imported waste to be landfilled by a

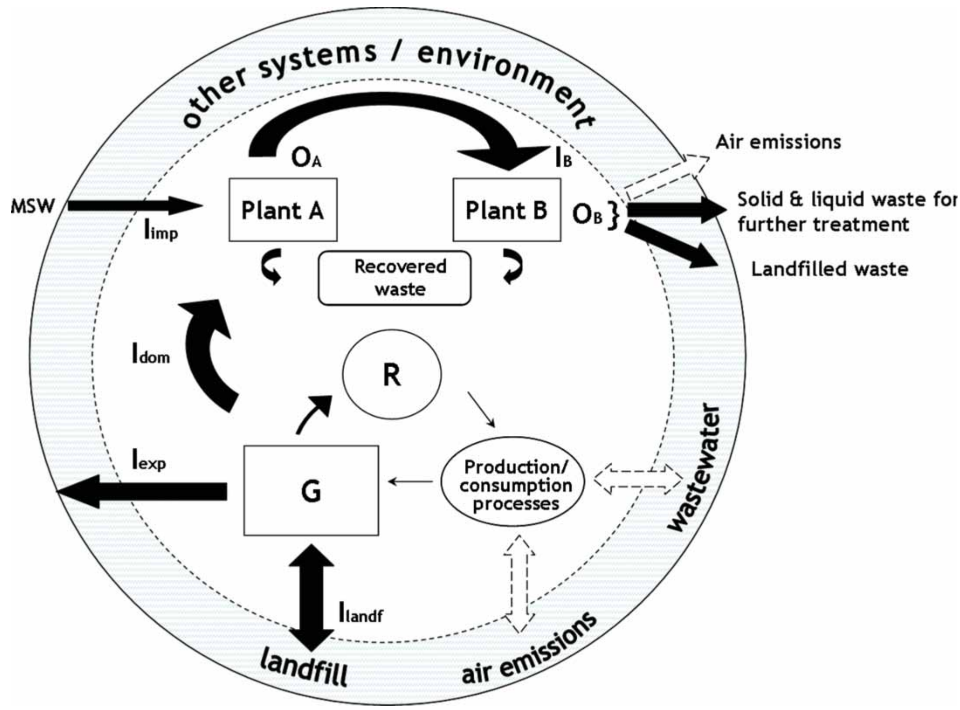

Figure 1. Schematic representation of a hypothetical system with two MSW-treatment facilities (A and B). The system limits are represented by the inner discontinuous circle. The solid black arrows represent flows included in the material accounting; the flows not considered are indicated by the white arrows in the dashed line. *G* stands for the MSW flow occurring from the production and consumption processes. *R* corresponds to the fraction of municipal or secondary solid waste directly used as raw material, either inside or outside the system's limits (Fragkou *et al*. 2010).

system is not accounted for as input to facilities or as an output. The system's output flows taken into account consist of the MSW directly sent to be treated in external facilities (I_{exp}) and the solid and liquid secondary waste flows generated in the system's MSW-treatment facilities (O_B) that are either exported for further treatment or deposited into the environment.

2.2 Definition and interpretation of the indicator

The indicator follows a holistic and descriptive approach for the evaluation of existing MSW-management plans in a predetermined system, following the whole life cycle of waste management. The assessment is made considering two important sustainability aspects: (i) the self-sufficiency in waste treatment[2] and disposal, and (ii) the system's capacity for closing material cycles through the recovery of the MSW that it generates.

The indicator is defined, for a specific time period, as the ratio of the sum of the materials recovered during the MSW treatment in the given system and the fraction of the MSW directly used as raw materials to the amount of MSW generated in the system. The facilities considered are all of the treatment plants in a system accepting MSW; these plants include composting, incineration and recycling facilities and more advanced mechanical and/or biological methods, such as anaerobic digestion and sorting plants.[3]

Green points and transfer centres are excluded because their inputs are normally equal to their outputs. The MSW-management self-sufficiency indicator, ws_x, for year x and for a system that consists of n municipalities, is calculated as follows:

$$ws_x = \left(\frac{\sum_{p=0}^{n} (I_{x,p} - O_{x,p}) + R_x}{G_x} \right), \tag{1}$$

where $I_{x,p}$ is the input of MSW-treatment plant p, located inside the system, for year x, in tonnes per year; $O_{x,p}$ is the amount of waste generated by MSW-treatment plant p, located inside the system, for year x, in tonnes per year; R_x is the amount of separately selected MSW used directly as raw materials for year x, in tonnes per year; G_x is the total amount of MSW generated by the studied system for year x, in tonnes per year.

The optimum value is considered to be one, not as an ideal value that can always suggest sustainable MSW practices but as a reference state corresponding to a socioeconomic system that recovers all of the MSW that it generates.[4] This value suggests an autonomous and self-sufficient system in the reuse, treatment and final disposal of MSW, accomplished by closing the system's material circles and avoiding the externalisation of the environmental risks associated with the related treatment processes and facilities. Nevertheless, this balance alone does not guarantee non-renewable resource conservation, and total waste generation has to be decreased in any case. Indicator values lower than one indicate systems that export or landfill a large amount of their MSW and whose recycling and/or reuse rates are minor; these systems essentially externalise the environmental risks related to MSW treatment and are potential generators of social conflicts, usually expressed as popular movements opposed to the siting of the treatment facilities. A value higher than one would indicate a system with the capacity to treat more MSW than it generates, but such a value does not imply an increase in the degree of sustainability for a given system. These values entail waste transport within systems, a critical stage of MSW-management plans that involves energy consumption and emissions of air pollutants (Buttol *et al*. 2007, Iriarte *et al*. 2009).[5]

3. Socioeconomic indicators

The concepts "environmental justice" and "environmental equity" are indiscriminately used to describe situations in which the risk of adverse outcomes due to environmental exposures is unevenly distributed throughout social groups. These social groups are defined by variables that are either demographic (such as age, gender, race or social class) or geographic (proximity to a high environmental and health risk-related installation).

To associate social and environmental sustainability, a number of the socioeconomic features of the studied systems' dwellers must be analysed. The majority of the relevant research focuses on the distributive impacts of environmental pollution across dimensions of class and race (Freeman 1972, Asch and Seneca 1978, Dorsey 1997, Bullard 2000, Pellow 2001). Considering the special characteristics of the chosen municipalities and the period of study, the race variables are not as relevant, given that it was only in the beginning of the twenty-first century that immigration flows arrived in the area. The exclusion of the race variable is also supported by the extended study of Ortega and Calaf (2010) in the area of study; their results did not reveal a correlation between the non-EU citizens' population and the siting of waste-treatment facilities. In view of that finding, our analysis focuses on the social class dimension of the population. The concept of the social class of a certain group can be defined in terms of the group's socioeconomic and cultural features (Ganzeboom and Treiman 1996, Bergman and Joyce 2001). In accordance with the available data, the key variables used in this work to characterise the social class of the studied groups are as follows:[6]

- *Average socioeconomic status*: Calculated by dividing the sum of the socioeconomic status of the people in the studied group (gross household income) by the total number of individuals in that group.
- *Unemployment rate*: Equal to the percentage of the unemployed population aged over 16 years old within the total active population.
- *Average studies level (30–39 years)*: The average educational level, in years of attendance, divided by the total number of people.
- *Post-compulsory education*: Refers to all studies after compulsory education.

To facilitate the association between the MSW-indicator performance and the social class of the case study's residents, the social key variables are calculated for each of the municipalities included in the case study.

To obtain comparable results and establish a gradation that reflects the degree of equity (ED) that represents the different variables studied, the average Catalan socioeconomic conditions are regarded as a reference state (the regional average). The calculation of the results for each of the studied parameters includes the difference between the value of the municipality studied (a) and the equivalent regional average value (b), divided by the same value of the regional average (b). The mathematical expression of this calculation is shown in Equation (2).

$$\mathrm{ED} = \frac{(a - b)}{b} \cdot 100. \qquad (2)$$

In this manner, if a municipality has an ED higher than 10% above the Catalan average, the population studied can be considered as an upper-middle class one. In the case in which this difference is up to 5%, the studied municipality lies within the average and can be described as middle-class. Finally, when the difference is negative and over 10%, the studied social group can be characterised as a lower-class one.

4. Case study presentation

The two indicators are applied to 12 of the coastal municipalities of Barcelona's Metropolitan Region. Barcelona is situated in Catalonia, a constituted autonomous community of Spain located in the north-eastern region of the Iberian Peninsula (Figure 2). The area 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. The selected systems have varying sizes in terms of population and covered area and demonstrate different socioeconomic conditions, and these systems were selected to achieve a broader comparison (Table 1).

The waste management in the area is under European, Spanish, Catalan and local legislation. The studied municipalities are under the control of the Metropolitan Authority of Barcelona, responsible for the waste management in the area. Based on its collection and treatment, the MSW collected in the studied system is classified as waste that is collected separately, to be recycled or recovered, and as waste destined, with no prior treatment, for

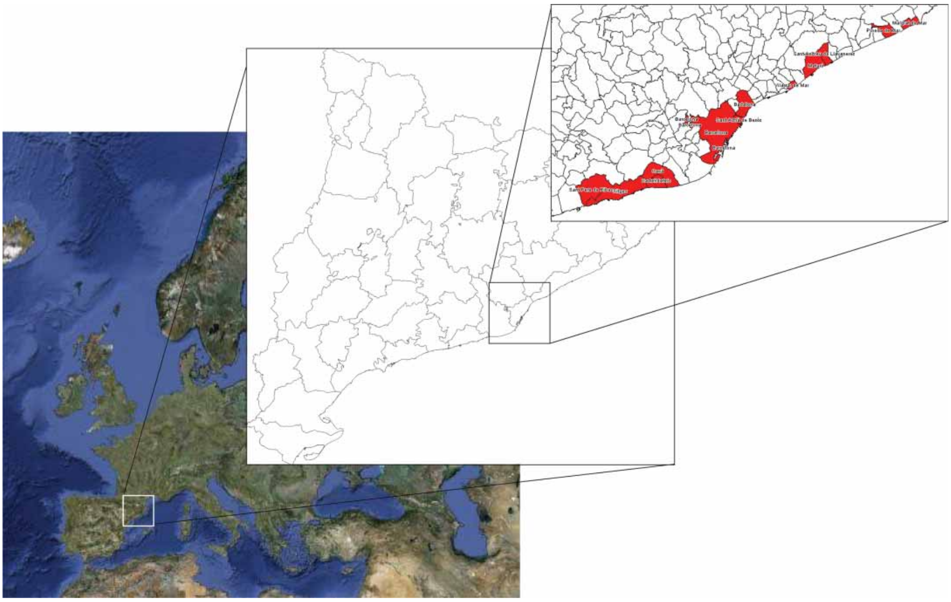

Figure 2. Location of Catalonia in Spain and Europe and the coastal municipalities under study.

energy recovery plants and controlled disposal. The region contains installations for the collection, separation and treatment of both of the types of waste. Currently, the separately collected MSW components are glass, paper and cardboard, light packaging, organic material and bulky waste. The existing final treatment facilities on the coast of the Barcelona Metropolitan Region include a controlled landfill site and two incinerator plants. Since 1998, the Metropolitan Authority of Barcelona has made a transition from incineration to the promotion of recycling and re-use for domestic waste through an ambitious policy plan (Llurdés *et al*. 2003).

Table 1. General characteristics and hosted MSWTF per municipality for 2001.

				Municipal waste facilities[a]	
County	Municipality	Population	Surface (km^2)	Number	Type
Garraf	Sant Pere de Ribes	22,902	40.8	0	–
	Sitges	20,345	43.8	0	–
Baix Lobregat	Castelldefels	46,786	12.9	1	CP
	Gavà	39,619	30.8	1	SP
Barcelonès	Barcelona	1,505,325	100.4	3	2 × ADP, CP
	Sant Adrià de Besòs	32,439	3.8	1	I
	Badalona	208,994	21.2	0	–
Maresme	Vilassar de Mar	17,374	4.0	0	–
	Mataró	107,191	22.5	1	I
	Sant Andreu de Llavaneres	7466	11.8	0	–
	Pineda de Mar	20,871	10.8	0	–
	Malgrat de Mar	14,246	8.9	0	–

Source: IDESCAT (2008)
[a]Facilities situated inside the municipality in 2001: CP, compost plant; SP, sorting plant; ADP, anaerobic digestion plant; I, incinerator.

Moreover, composting is a common practice, greatly favoured not only by EC Directives, but also by Catalan regulations; the Municipal Waste Management Program in Catalonia (2001–2006), in force during the period of study, set objectives for the separate collection of each of the fractions of MSW and planned to impose a tax on landfilling to encourage separate collection and recycling. Yet, the amount of organic matter collected separately does not reach the amount of residues directly sent for final treatment, whether that final treatment is landfill or incineration.

With regard to environmental justice studies in the area, a relevant report was published in 2010 by Ortega and Calaf (2010), revising the state of environmental equity in all of Catalonia. The authors analyse the association between income and the siting of municipal and industrial waste facilities as well as the access to environmental services, among other factors. According to their results, the selected municipalities are situated in the zone with the highest density of municipal waste facilities, a fact that gives more relevance to our study.

5. Results

Due to restrictions of data availability, the waste and social indicators are calculated and compared for the year 2001. This year is the most recent year for which socioeconomic statistics could be found because it is the last year in which a population census was performed in the area of study.

5.1 Results of the MSW-management self-sufficiency indicator

The MSW-indicator value depends heavily on the fraction of generated MSW that is directly used as raw material (R) and, in the case of systems hosting-related treatment facilities, on the performance of these plants.[7] For systems with no MSW-treatment capacity, the indicator value is solely attributed and is analogous to the fraction of MSW directly recovered (R). The majority of the waste-indicator values presented in Table 2 are less than or equal to 0.10 and correspond to such municipalities; their low values indicate small direct-recovery rates (see the R fraction in the same table). These systems export almost the entirety of their MSW for treatment outside their limits (each of them exports more than 90% of its MSW), externalising in this way the environmental costs associated with MSW treatment.

Sant Adrià de Besòs and Mataró present extremely high indicator values; both of these municipalities host incinerator plants, and their ws_x values are analogous to their facilities' inputs. These facilities principally serve the municipalities belonging to the Barcelona Metropolitan Area and the County of Maresme, respectively. The two systems share the common characteristics of very high rates of MSW imports and correspondingly low percentages of exported waste in relation to the MSW that they generate. Although these systems appear more self-sufficient in terms of MSW-treatment capacity, they are receptors of large amounts of waste from neighbouring systems and the environmental hazards associated with the function of these facilities. Additionally, these municipalities seem to rely greatly on these facilities and demonstrate lower material recovery than most systems.

The three municipalities with moderate results, meaning values between 0.20 and 0.75, are those that either host material-recovery facilities, such as compost and sorting plants, with small secondary waste flows that favour the indicator (Gavà and Castedellfels) and the case of Sant Andreu de Llavaneres with a very high R value. In the first case, these municipalities are systems that receive low fractions of MSW compared to their local generation, and although they demonstrate relatively satisfactory R values, they still need to export a large amount of their MSW.

Table 2. Results for the MSW-management self-sufficiency indicator for 2001.

Municipality	MSW generation (*t*/*y*)	Waste treated (*t*/*y*)	Plant outputs (*t*/*y*)	Imported waste[a] (%)	Exported waste[b] (%)	*R* (%)	ws_x
Sant Pere de Ribes	12,753	0	0	0.0	93.8	0.0	0.00
Sitges	17,943	0	0	0.0	96.3	1.2	0.01
Castelldefels	37,159	7103	0	7.6	84.8	3.7	0.23
Gavà	23,192	12,158	2189	51.7	92.3	4.5	0.48
Barcelona	746,431	11,163	3386	1.5	92.5	6.0	0.07
Sant Adrià de Besòs	14,968	300,593	8332	2008	6.7	2.5	19.55
Badalona	96,062	0	0	0.0	95.3	4.7	0.05
Vilassar de Mar	9963	0	0	0.0	97.8	2.2	0.02
Mataró	61,681	197,076	0	319	21.8	4.4	3.24
Sant Andreu de Llavaneres	5470	0	0	0.0	68.8	31.2	0.31
Pineda de Mar	16,984	0	0	0.0	96.5	3.5	0.03
Malgrat de Mar	13,078	0	0	0.0	97.3	2.7	0.03

[a]Percentage of the total waste treated in the system.
[b]Percentage of the total waste generated in the system.

5.2 Results of the environmental justice indicators

The social indicators examined include the unemployment rate, the average socioeconomic conditions in a municipality, the average educational level of its residents and their studies further than that of the obligatory education. In Table 3, all of the indicators are given with relation to the average values for the entirety of Catalonia as a reference state.

As we can see, there are four municipalities (Sant Adrià de Besòs, Pineda de Mar, Badalona and Malgrat de Mar) that are among the cities with the highest relative unemployment

Table 3. Relative weight of each key variable for 2001.[a]

Municipality	Unemployment	Average socioeconomic conditions	Average educational level	Postgraduate education
Sant Pere de Ribes	−4.3	−3.6	−4.5	−18.6
Sitges	7.0	7.3	9.4	24.8
Castelldefels	4.6	3.6	3.8	−1.7
Gavà	1.2	−5.5	−1.7	−5.5
Barcelona	8.5	2.7	8.7	28.2
Sant Adrià de Besòs	52.9	−12.7	−8.3	−37.2
Badalona	32.3	−9.1	−6.6	−18.3
Vilassar de Mar	−6.5	6.4	6.3	27.4
Mataró	27.6	−1.8	−8.7	−19.8
Sant Andreu de Llavaneres	−26.0	10.9	6.3	22.3
Pineda de Mar	50.4	−6.4	−12.2	−22.0
Malgrat de Mar	30.3	−2.7	−8.0	−26.0

Source: IDESCAT (2008).
[a]Social parameters considered, as calculated in Equation (2).

rates and the lowest relative socioeconomic conditions, educational and post-compulsory education levels. Even the city of Mataró can be included here, despite the fact that some of the indicator values for this city do not reach the extremes of this category. According to the social class concept, these municipalities can be typically considered as working-class societies.

In contrast, there are two municipalities (Vilassar de Mar and Sant Andreu de Llavaneres) that are among the cities with the lowest relative unemployment rates and the highest socioeconomic conditions, educational and post-compulsory education level. Even the municipalities of Sitges and Barcelona can be added to this category (with the exception of the relative unemployment rates, although the rates in these municipalities are much lower than those of the municipalities in the former category). These municipalities host an upper-middle-class population. The rest of the municipalities of the area (Gavà, Castelldefels and Sant Pere de Ribes) can be typically classified as middle-class.

5.3 Comparison between the two indicators

All of the municipalities that present lower ED values and correspond to working-class societies have a poor performance in the ws_x indicator. However, there is a clear distinction between these two contrasting categories: systems with extremely high and low values. The former group includes the municipalities that host incineration plants (i.e. Sant Adrià de Besòs and Mataró). These two municipalities share the common characteristics of very high rates of imports and correspondingly low percentages of exported waste in relation to the MSW that they generate. These municipalities also demonstrate low percentages of directly recovered MSW for the year 2001, which forms another indicator of poor performance regarding management. In the totality of the municipalities studied, these municipalities are the ones that experience the most environmental injustice, accepting large amounts of MSW and the incineration plant-related health and environmental hazards.

The low ws_x indicator-value category includes lower-class municipalities that export all of their MSW (namely, Badalona, Pineda de Mar and Malgrat de Mar). These municipalities are too small to host any treatment facilities; nonetheless, exports could be drastically reduced through an effective separation and collection scheme as well as the use of other practices, such as composting at home, that could result in the minimisation and recovery of all of the waste generated. In contrast, the poor sustainability of these municipalities' MSW-management plan is expressed by the low figure of directly reused MSW (the *R* fraction; see Table 4).

Two of the middle-class municipalities, Gavà and Castelldefels, are the most sustainable ones of all of the studied systems. Not only are these municipalities among the three municipalities with better results for the ws_x indicator, i.e. closer to a value of one, but they also show good percentages of direct reuse of their MSW (*R* fraction). Both of these municipalities host MSW-treatment plants, importing MSW for treatment, yet, they still export a large percentage of their domestic MSW. The third municipality of this class, Sant Pere de Ribes, demonstrates a distinct behaviour because there is no direct reuse, and the totality of its MSW is exported.

All of the municipalities classified as upper-middle class (i.e. Vilassar de Mar, Sitges, Sant Andreu de Llavaneres and Barcelona) have as a common characteristic the export of the majority of their MSW for treatment. As a consequence, these municipalities lie among the municipalities with the worst performance according to the MSW-management self-sufficiency indicator. There are, however, two exceptions to this category. The first exception is the case of Sant Andreu de Llavaneres, which demonstrates a

Table 4. Comparison of the studied indicators for the year 2001.

Municipality	Social class	ws*x*	*R* (%)
Sant Pere de Ribes	Middle	0.00	0.0
Sitges	Upper-middle	0.01	1.2
Castelldefels	Middle	0.23	3.7
Gavà	Middle	0.48	4.5
Barcelona	Upper-middle	0.07	6.0
Sant Adrià de Besòs	Lower	19.55	2.5
Badalona	Lower	0.05	4.7
Vilassar de Mar	Upper-middle	0.02	2.2
Mataró	Lower	3.24	4.4
Sant Andreu de Llavaneres	Upper-middle	0.31	31.2
Pineda de Mar	Lower	0.03	3.5
Malgrat de Mar	Lower	0.03	2.7

rather satisfactory performance in terms of MSW-management self-sufficiency. Although this municipality does export its MSW for treatment, its high direct-reuse percentage (*R*) correspondingly diminishes the amount of waste to be exported. The other exception is the municipality of Barcelona. Of all of the upper-middle class municipalities, Barcelona is the only one that hosts MSW-treatment facilities. However, there is a significant difference between the facilities that Barcelona and lower-income municipalities host. The former hosts two anaerobic digestion plants and one compost plant, all situated in the state-of-the-art Ecoparc of Barcelona, for the recovery of the organic and non-selected MSW fractions. In contrast, the poorer municipalities host older incineration facilities, clearly more questionable in terms of public acceptance and operation-associated hazards.

From all of the above material, we can deduce that there is no firm and absolute connection between social class and performance in the MSW-management indicator. Yet, there is a general pattern that (i) associates middle-class municipalities with better performance in the indicator, (ii) reveals that upper-middle-class municipalities export all of their MSW for treatment, and in the case they host MSWTF, these facilities are not installations that cause public disturbance, (iii) demonstrates that poorer municipalities host the most hazardous and publicly controversial MSWTF and (iv) reveals that working-class municipalities are more likely to be involved in issues of environmental injustice, either as receptors of disproportionate amounts of MSW, compared to what they generate, or as systems that export waste and demonstrate low performance in the direct reuse of their MSW.

The last finding is rather interesting because it shows that MSW-management plans are practically neglected in poorer municipalities. Very little effort seems to be made for the "protection" of their inhabitants, expressing social sustainability, or in the promotion of closing their material cycles through direct reuse, as a statement of environmental sustainability.

6. Discussion

The metabolic analysis of MSW flows allows researchers to examine the correlation between social class and the externalisation of burdens associated with the treatment of waste. All of the studied systems export waste for treatment, yet the upper-middle and middle-class municipalities are those that mostly rely on this practice. Working-class municipalities either depend largely on their facilities, achieving a high degree of self-sufficiency, or the amount of waste that they export is minor.

Regarding imports, these are directly linked to the number and type of facilities hosted in each system. Imports of MSW take place almost exclusively in the lower-class municipalities that host incineration plants. Smaller amounts of imports occur in Castelldefels, Gavà and Barcelona. These municipalities of middle and upper-middle class host the less polluting and hazard-associated facilities of composting, sorting and anaerobic digestion. Based on the above remarks, we can identify a correlation between social class and the hosting of MSW-treatment facilities, not merely in terms of quantity but also in terms of public acceptance. As the social class of a municipality is raised, the municipality is not only less likely to have a MSW facility but also, if it would host a facility, the facility would probably be an installation considered acceptable by its dwellers. Bearing in mind that social classes reflect power relations, we can assume that waste management takes place within social and political processes in which some social groups have more power over others when the relevant decisions are made. This conclusion corroborates the findings of Ortega and Calaf (2010), who found a negative correlation between income and proximity to municipal waste-treatment infrastructure for the entirety of Catalonia.

Concerning the objective of correlating social class and ecological sustainability, the results do not demonstrate a clear connection between socioeconomic indicators and the closing of material cycles (R value). Of the four upper-middle-class municipalities, for example, two of them occupy the first two positions in the direct recycling ranking (Barcelona and Sant Andreu de Llavaneres), while the other two have the worst performance (Vilassar de Mar and Sitges). Nevertheless, the average R value per social class depicts a clearly better performance of the higher-class municipalities. These municipalities present an average value of 10.15%, while the middle- and working-class systems' values are equal to 2.7% and 3.56%, respectively. This fact reveals that the upper-middle-class municipalities have more opportunities to close their material cycles, most likely attributable to better infrastructure for separate collection of MSW and the application of more efficient management schemes.

The analysed data demonstrate a low degree of sustainability, in terms of MSW-management self-sufficiency, in the municipalities where the dominant social class is either working (e.g. Sant Adrià de Besòs and Mataró) or upper-middle (e.g. Vilassar de Mar and Sitges). In the first case, lower-class municipalities treat on their premises more waste than they generate, resulting in disproportionate potential health and environmental hazards for their residents. Upper-middle-class municipalities have a poor sustainability performance because they externalise the environmental risks associated with the waste-treatment facilities by sending the majority of their waste to be treated in other municipalities.

The above findings indicate that the ws_x indicator is more relevant and holistic than the R indicator in describing a social system's path to managing its waste sustainably, not only in an environmental but also in a social manner. Established recycling and material recovery indicators, such as R, are only capable of capturing the physical dimension of MSW treatment. Imports and exports of waste are not considered, omitting the associated externalities, and as a result, the social behaviour of a system cannot be reflected with these broadly used yet one-dimensional sustainability indicators. The ws_x indicator manages to capture and reflect both the environmental and social performance of a system regarding MSW management.

Subsequently, the accounting of municipal waste flows proves to be a valuable tool in supporting policy-making. On one hand, waste accounting can be useful to evaluate existing situations because it facilitates records of the imported and exported flows of waste and generates a self-sufficiency index for each territorial unit (e.g. municipalities, counties, regions). This diagnosis not only allows the identification of situations of environmental injustice and facilitates comparisons between systems but is also useful for correcting procedural and political inequalities associated with MSW management, through the redesign of more sustainable and socially just waste-management schemes. On the other hand, the proposed approach can be even more useful for the design of new MSW policies at the local level. The fact that systems of different social classes demonstrate varying degrees of sustainability in MSW management (according to the ws_x indicator) can help policy-makers to plan distinct and modified waste-management strategies adapted to each location, depending on the social structure of each system.

Additionally, our model can help decision-makers to pursue sustainability goals and prioritise MSW-management strategies. The main results of our case study demonstrate a need for the promotion of waste minimisation and maximisation of recycling and recovery rates. These strategies reduce waste flows between systems, a major cause of social and environmental inequalities.

7. Conclusions

In this paper, we examined the relevance of the social dimension of MSW management to investigate whether there is a correlation between social and environmental sustainability. Four key variables were considered to characterise 12 selected municipalities in terms of social class. At the same time, an indicator based on a metabolic analysis of MSW flows was applied to each system to examine (i) the system's efficiency in closing its material cycles through the recovery of MSW, corresponding to an indicator of environmental sustainability, and (ii) the MSW export and import flows, as an indicator of social sustainability. The objective was to discover whether there is an association between socioeconomic groups and the results of these indicators.

The findings indicate that the MSW self-sufficiency indicator, although a "physical" dimension indicator, satisfactorily addresses the social status dimension of each system analysed because a high degree of correspondence is observed between the two variables. This indication contributes to emphasising the importance of the social dimension of sustainability, especially if we keep in mind that, historically, the concept of sustainability was based on its economical and natural (environmental) dimensions, while the social dimension is part of the great declarations of principles but does not always gain full recognition in the empirical implementation of sustainability. This finding is complemented by the conclusion that MSW management is not only a technical issue but also a social and political one. The model developed here provides some evidence on the interrelationships between these dimensions and also a key political implication: waste-management strategies should be adapted to the social structure of each territory.

The "social class" indicators allow the classification of different municipalities according to their social and economic status, and in combination with the ws_x indicator, we can see how the municipalities where people have a higher social class have MSW-management schemes that are typically based on export strategies. In contrast, municipalities where lower social classes predominate are net importers of MSW. Both of these approaches demonstrate low self-sufficiency and sustainability, and these municipalities' management strategies seem to be far from MSW trends and recommendations for minimising waste generation through reduced or more responsible consumption (Baker *et al*. 2004, p. 26).

In this sense, the data obtained in our research seem to support the hypothesis that greater social equity, in terms of education quality, distribution of economic resources and infrastructure, for example, may offer greater opportunities to perform more sustainable

MSW management. Defending this hypothesis would certainly require a deeper analysis of the factors that can explain this correlation in more detail, yet this objective exceeds the scope of this text and is proposed to be included in future lines of work. At the moment, we can suggest that higher-class municipalities demonstrate a considerably better average performance regarding direct recovery rates. This fact can be attributed to the infrastructure and availability of resources to which wealthier municipalities have access. Another factor was identified as influencing the percentage of MSW sent for direct material recovery; in the cases in which the municipality is under the jurisdiction of a broader regional environmental plan, the municipality's recovery rates are higher, apparently due to the effectiveness of a broader organisational scheme.

Based on the above findings, we can argue that in the studied system, environmental and health protection appears to be a privilege of higher-income municipalities. In systems with lower socioeconomic characteristics, one detects inefficient MSW-management policies not only for the welfare of its citizens, regarding the location of treatment facilities, but also with regard to environmental sustainability. In this sense, the results of our study expose the utility of a quantitative approach to environmental justice problems. The application of the suggested approach to other cases can prove to be a useful tool for the prediction and even prevention of the occurrence of similar inequalities.

Overall, the results of this study indeed verify our assumption regarding the association between environmental and social sustainability; at the same time, the results reveal the need for comprehensive and interdisciplinary sustainability indicators as indispensable tools for monitoring not only the physical equilibrium between social and natural systems, but also the social equity among human societies.

Acknowledgements

Financial support was provided by the Interreg IIIC SUDOE project (ECOTEC_SUDOE SOE/P2/E377). The authors thank the two anonymous reviewers for their valuable comments and suggestions.

Notes

1. Although landfill sites are traditionally generators of environmental conflicts and have low popularity in public opinion, we choose to omit these facilities from our study. In addition to the methodological restrictions mentioned above, the diversion of MSW from being landfilled is a main goal of recent MSW legislation at all administrative levels (see Section 4 for more details). Consequently, the number of landfill sites is gradually reduced and accordingly so is the relevance of landfill sites in environmental justice studies.
2. As stated in the Directive 2008/98/EC of the European Parliament and of the Council on Waste (European Commission 2008).
3. The generic term "treatment plants" that will be used from now on also includes sorting plants. Because the difference between their inputs and outputs corresponds to recovered material, we consider sorting plants as treatment plants in this methodology.
4. Following the indicator's mathematical expression (Equation (1)), this value can be equal to unity when both of the following conditions are met: (i) all of the MSW generated (G) is either directly reused (R) or treated inside the system ($I_{x,p}$) with zero outputs ($O_{x,p}$), and (ii) no fraction of the MSW generated (G) is sent to landfill ($I_{\text{landf}} = 0$) or exported ($I_{\text{exp}} = 0$).
5. For a more detailed analysis on the importance of the transport stage in a MSW-management scheme, see Fragkou *et al.* (2010).
6. When preparing the indicator, variables such as the percentage of people older than 65 years (retired) and the percentage of people born in a foreign country were taken into account, among others, but these variables were rejected because of their low discrimination power.
7. See Equation (1).

References

Alió, M.A., 2008. *La difícil transición hacia la prevención: una visión desde el análisis de las políticas sobre el reciclaje de residuos urbanos. Diez años de cambios en el Mundo, en la Geografía y en las Ciencias Sociales, 1999–2008. Actas del X Coloquio Internacional de Geocrítica, Universidad de Barcelona, 26–30 de mayo de 2008* [online]. Available from: http://www.ub.es/geocrit/-xcol/75.htm [Accessed 12 June 2010].

Asch, P. and Seneca, J., 1978. Some evidence on the distribution of air quality. *Land Economics*, 54 (3), 278–297.

Baker, E., Bournay, E., Harayama, A. and Rekacewicz, P., 2004. *Vital Waste Graphics*. Nairobi: United Nations Environment Programme.

Beck, U., 1992. *Risk society. Towards a new modernity*. London: Sage.

Bergman, M. and Joyce, D., 2001. *Comparing social stratification schemas: CAMSIS, CSP-CH, Goldthorpe, ISCO-88, Treiman, and Wrihght*. Cambridge Studies in Social Research, No. 10. Cambridge: SSRG Publications.

Bullard, R., 1993. *Confronting environmental racism: voices from the grassroots*. Boston: South End Press.

Bullard, R., 1994. *Unequal protection: environmental justice and communities of color*. San Francisco: Sierra Club Books.

Bullard, R., 2000. *Dumping in Dixie: race, class, and environmental quality*. Boulder, CO: Westview Press.

Bullard, R., 2005. *The quest for environmental justice: human rights and the politics of pollution*. San Francisco: Sierra Club Books.

Buttol, P., *et al.*, 2007. LCA of integrated MSW management systems: case study of the Bologna District. *Waste Management*, 27 (8), 1059–1070.

Carr, G., 1995. Environmental equity: does it play a role in WTE siting? *Journal of Hazardous Materials*, 47 (1–3), 303–312.

Curtice, J., *et al.*, 2005. *Public attitudes and environmental justice in Scotland: a report for the Scottish executive on research to inform the development and evaluation of environmental justice policy*. Edinburgh: Scottish Executive Social Research.

D'Alisa, G., Di Nola, M.F., and Giampietro, M., 2012. A multi-scale analysis of urban waste metabolism: density of waste disposed in Campania. *Journal of Cleaner Production*, 35, 59–70.

Dorsey, M., 1997. Environmental justice: issues of racism, poverty and the environment. *Capitalism Nature Socialism*, 8 (3), 139–146.

European Commission, 2008. *Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste*. Brussels: European Commission.

Eurostat, 2001. *Economy-wide material flow accounts and derived indicators – a methodological guide*. Luxembourg: Office for Official Publications of the European Union.

Faber, D., 1998. *The struggle for ecological democracy: environmental justice movements in the United States*. New York: The Guilford Press.

Fischer-Kowalski, M., 1998. Society's metabolism. The intellectual history of materials flow analysis. Part I: 1860–1970. *Journal of Industrial Ecology*, 2 (1), 61–78.

Fragkou, M., Vicent, T., and Gabarrell, X., 2010. A general methodology for calculating the MSW management self-sufficiency indicator: application to the wider Barcelona area. *Resources, Conservation and Recycling*, 54 (6), 390–399.

Freeman, A., 1972. Distribution of environmental quality. *In*: A. Kneese and B. Bower, eds. *Environmental quality analysis: theory and method in the social sciences*. Baltimore: Resources for the Future, 243–265.

Furuseth, O. and O'Callaghan, J., 1991. Community response to a municipal waste incinerator: NIMBY or neighbor? *Landscape and Urban Planning*, 21 (3), 163–171.

Futrell, R., 2000. Politics of space and the political economy of toxic waste. *International Journal of Politics, Culture and Society*, 13 (3), 447–476.

Ganzeboom, H. and Treiman, D., 1996. Internationally comparable measures of occupational status for the 1988 international standard classification of occupations. *Social Science Research*, 25 (3), 201–239.

GAO, 1983. *Siting of hazardous waste landfills and their correlation with racial and economic status of surrounding communities*. Washington, DC: GPO.

Hofrichter, R., 1993. *Toxic struggles. The theory and practice of environmental justice*. Philadelphia: New Society Publishers.

Hsu, H., 2006. NIMBY opposition and solid waste incinerator siting in democratizing Taiwan. *The Social Science Journal*, 43 (3), 453–459.
Hunter, L., *et al.*, 2003. Environmental hazards, migration and race. *Population and Environmental*, 25 (1), 23–39.
IDESCAT, 2008. *Territory: municipal databases. Official statistics website of Catalonia* [online]. Statistical Institute of Catalonia. Available from: http://www.idescat.cat/ [Accessed 5 May 2008].
Iriarte, A., Gabarrell, X., and Rieradevall, J., 2009. LCA of selective waste collection systems in dense urban areas. *Waste Management*, 29 (2), 903–914.
Joos, W., *et al.*, 1999. Social aspects of public waste management in Switzerland. *Waste Management*, 19 (6), 417–425.
Konisky, D., 2008. Inequities in enforcement? Environmental justice and government performance. *Journal of Policy Analysis and Management*, 28 (1), 102–121.
Krueger, R. and Agyeman, J., 2005. Sustainability schizophrenia or "actually existint sustainabilities?" toward a broader understanding of the polítics and promise of local sustainability in the US. *Geoforum*, 36 (4), 410–417.
Llurdés, J., Sauri, D., and Cerdan, R., 2003. Ten years wasted: the failure of siting waste facilities in central Catalonia, Spain. *Land Use Policy*, 20 (4), 335–342.
Macintyre, S., Macdonald, L., and Ellaway, A., 2008. Do poorer people have poorer access to local resources and facilities? The distribution of local resources by area deprivation in Glasgow, Scotland. *Social Science and Medicine*, 67 (6), 900–914.
Massoud, M., El-Fadel, M., and Abdel Malak, A., 2003. Assessment of public vs private MSW management: a case study. *Journal of Environmental Management*, 69 (1), 15–24.
OECD Environmental Directorate, 2004. *Environmental and distributional issues: analysis, evidence and policy implications*. Paris: OECD, Environment Policy Committee.
Ortega, M. and Calaf, M., 2010. *Equitat ambiental a Catalunya: Integració de les dimensions ambiental, territorial i social a la presa de decisions. Generalitat de Catalunya Departament de la Vicepresidència Consell Assessor per al Desenvolupament Sostenible de Catalunya.* Catalonia: CADS.
Pastor, M., Sadd, J., and Hipp, J., 2002. Which came first? Toxic facilities, minority move-in, and environmental justice. *Journal of Urban Affairs*, 23 (1), 1–21.
Pellow, D., 2001. Environmental justice and the political process: movements, corporations, and the state. *Society Quarterly*, 42 (1), 47–67.
Petts, J., 1994. Effective waste management: understanding and dealing with public concerns. *Waste Management and Research*, 12 (3), 207–222.
Pulido, L., 1996. *Environmentalism and economic justice*. Tucson: The University of Arizona.
Ringquist, E., 1997. Equity and the distribution of environmental risk: the case of TRI facilities. *Social Science Quarterly*, 78 (4), 811–829.
Ringquist, E., 2005. Assessing evidence of environmental inequities: a meta-analysis. *Journal of Policy Analysis and Management*, 24 (2), 223–247.
Rives, J., Rieradevall, J., and Gabarrell, X., 2010. LCA comparison of container systems in municipal solid waste management. *Waste Management*, 30 (6), 949–957.
Schnaiberg, A., 1980. *The environment: from surplus to scarcity*. New York: Oxford University Press.
Schnaiberg, A., Weinberg, A., and Pellow, D., 1998. Politicizing the treadmill of production: reshaping social outcomes of 'Efficient' recycling. *Revista Internacional de Sociologia*, 19–20, 181–222.
US EPA, 1992. *Environmental equity: reducing risk for all communities. Volume 2: supporting document*. Washington: US Government Printing Office.
US EPA, 2008. El medio ambiente y su salud: Justicia ambiental y participación comunitaria [online]. Available from: http://www.epa.gov/espanol/saludhispana/justicia.htm [Accessed 14 April 2008].