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REGIONAL CASE STUDY

Waste management assessment in Geneva through material system and resource analysis

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Abstract In the canton of Geneva, public authorities use infrastructural and persuasive instruments to favour household waste sorting. The cantonal fund for waste management (CFWM) partly finances these policy instruments. The aim of this study is to assess household waste management (WM) in Geneva with a focus on waste sorting and the operation of the CFWM. This study relies on a new assessment method which combines material system analysis and policy analysis. This combination analyses how the resources used for household WM influence the state of the WM system. The assessment shows that the resources used by public authorities led to a growth in waste sorted and a decrease in waste incinerated in Geneva over the period 2002–2013. This trend, combined with a strong decrease in imported waste, induced the monopolisation by waste collection centres of the available funds in the CFWM budget at the expense of cantonal raising awareness. The assessment leads to two recommendations for decision makers. First, a policy instrument mix based on infrastructural and persuasive instruments constitutes an effective approach to favour waste sorting by households. Second, the use of a "disposal tax" does not constitute a sustainable approach to finance the operating costs of the sorting infrastructure.

Keywords Canton of Geneva · Resources · Household waste management · Assessment · Material system analysis · Policy analysis

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Introduction

According to Zurbrügg et al. [1], an assessment of a waste management (WM) system should provide both comprehensive knowledge of the system and practical information for decision makers and researchers. Material system analysis methodologies, including material flow analysis [2], enable a description of WM by mapping the material cycle of waste through a meso-level analysis [3, 4]. These quantitative methodologies fail, however, to explain the underlying drivers of the WM system. Thus, they only aim to describe waste movements within and outside the system. Policy analysis allows for identification of these drivers through the analysis of different immaterial and material resources, i.e., infrastructural, financial, cognitive, organisational, and legal resources [6], used by public actors in the framework of waste policy. Therefore, the combination of these two approaches should provide a reliable interdisciplinary perspective to assess WM practices.

The main aim of Genevan waste policy is to implement waste sorting for households through a mix of policy instruments [5]. This instrument mix relies on infrastructural (e.g., collection points or kerbside collection) and persuasive instruments (e.g., campaigns to raise awareness) [6, 7]. Moreover, Genevan authorities use a financial mechanism, i.e., the cantonal fund for waste management (CFWM), to partly finance these instruments. This study presents an assessment of household WM in Geneva. The assessment focuses on the evolution of household waste sorting and the operation of the CFWM. Thus, it relies on a combined analysis of the resources used by public and private actors for WM and of the state of the material system of WM. It covers the period from 2002 to 2013. This period corresponds to the introduction of a new waste

policy [8] and the full implementation of two WM plans [9, 10].

The next section presents the case study and method employed for the assessment. The section on the results and discussion describes the functioning of the household WM system in 2002 and its evolution until 2013. Moreover, it presents the effects and lessons learned relative to household waste sorting and the operation of the CFWM. The conclusions provide key recommendations for decision makers concerning household waste sorting, stemming from the practices in Geneva.

Materials and methods

Study area and Genevan household waste

The study area is the canton of Geneva (hereinafter, Geneva) in Switzerland. It constitutes one of the wealthiest regions in the world [11] and has a high population density (i.e., over 1800 inhabitants per km^2) with a high turnover of the Genevan population [12, 13]. It comprises 45 municipalities. The main one is the city of Geneva. It houses 40% of the Genevan population. Its economy mainly relies on the tertiary sector, i.e., the finance sector and international organisations [14].

The assessment focuses on waste from Genevan households (as shown in Table 1). It also covers household waste treated in Geneva which originates from some surrounding jurisdictions. Moreover, it includes waste from small enterprises collected by the Genevan municipalities and waste from cantonal and municipal authorities [8, 10]; these waste flows, which cannot be quantified due to lack of data, have a similar composition to household waste. In the interest of simplification, the assessment excludes hazardous waste (i.e., batteries, etc.), electric and electronic waste, and waste generated in small quantities (i.e., oil, textiles, etc.).

Methods

The assessment method relies upon a joint analysis of the evolution of the public resources mobilised and the private resources regulated by public authorities within the framework of Genevan waste policy (see circle 1 in Fig. 1)

Table 1 Types of urban waste covered in the case study

Mixed waste	Paper	Glass
Bulky waste	Wood	PET bottles
Food waste	Iron and aluminium	Metal
Garden waste	Rubble	

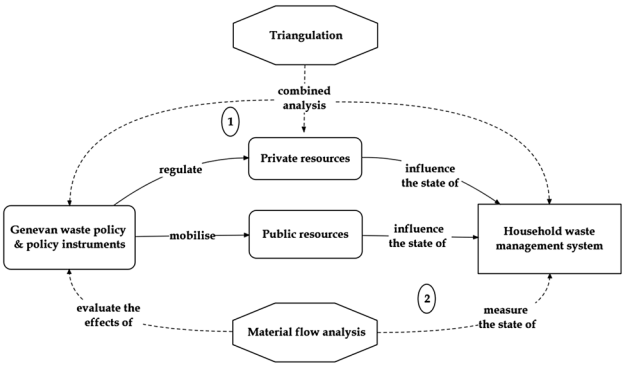

Fig. 1 Illustration of the assessment method

and their influence on the state of the household WM system (see circle 2 in Fig. 1). Thus, this assessment method aims to examine how changes in the public and private resources influence the state of the household WM system over time, i.e., the waste movements. The material and immaterial resources [6] constitute the object of analysis. They represent the link between the waste policy and the WM system.

First, with regard to the policy analysis perspective, resources enable public and private actors to achieve an activity [15]. Moreover, they constitute levers of action for public policy and its related policy instruments in addition to exerting a significant influence on processes, results, and effects [6, 15]. This examination of public and private resources and Genevan waste policy relies on the triangulation as shown in Fig. 1. This approach, based on multiple research methods, is employed in both policy evaluation [16] and environmental policy evaluation [17]. It serves to empirically examine the impact of a policy using several methods and sources of data instead of only one. It enables a comparison and overlap of different results to enhance the validity and reliability of existing observations about a given situation [18]. Therefore, this examination of resources and waste policy relies on documentary analysis [19] of Swiss and Genevan documents and interviews [19] with public and private stakeholders. It also relies on a secondary analysis [20] of (1) public data from Genevan waste statistics and inventories [21, 22], (2) non-public data from the database of Genevan waste inventories, and (3) public data from the Genevan public utility enterprise [23–25]. These methods serve also to define the household WM system.

Second, into the context of the material system analysis, the resources represent tangible and intangible elements contained in the structure of the system defining its state [26]. They thus constitute causal factors and underlying drivers that influence the state of a material system at a given time [27]; the public and private resources define the state of the household WM system. The analysis relies on

the MFA method [2] as shown in Fig. 1. This method allows to examine in quantitative terms the anthropogenic metabolism by providing mass-flow indicators on waste movements to evaluate the effects of the Genevan waste policy as shown in Fig. 1.

With regard to the use of the MFA method, it must be noted that this study does not integrally use the methodology of Baccini, Brunner and Rechberger [2, 27] for the sake of simplicity. This study follows the material flow modelling of Meylan et al. [28] and Matsubae-Yokoyama et al. [29]. Thus, the household WM system only includes the waste stream defined in Table 1. It does not consider the outputs of waste treatment processes such as compost from composting centres. The WM system is hence modelled to follow the waste movements from their generation and collection until treatment. Therefore, the mass balance, i.e., the principle of conservation of mass, is not taken into account for waste treatment processes as such, i.e., waste incineration and recovery of organic waste. However, the mass balance from waste generation/collection until entrance to the waste treatment process inside or outside the WM system is respected.

Results and discussion

Resources used by the household WM system in 2002

This section focuses on material and immaterial resources used in 2002 by public and private actors (listed in Table 2) for the separate collections of waste, their organic recovery, their recycling outside Geneva, and the incineration of combustible waste. Thus, this section explains the functioning of the household WM system in 2002 which took up approx. 197,054 tonnes (t) of waste generated by Genevan households and 88,352 t from outside, as shown in Fig. 2. Four key features described the system in 2002.

First, the Genevan municipalities collected separated fractions, i.e., paper, glass, PET bottles, aluminium and iron, through kerbside collection and/or collection points (see infrastructural resources in Table 2). Moreover, eighty-five per cent of Genevan municipalities, i.e., 36 of the 45 municipalities, collected garden waste, but only forty-four per cent, i.e., 19 of 45 municipalities, did this for food waste (with or without garden waste). The financing of these collection operations came mainly from municipal taxes [30] (see financial resources in Table 2). Cantonal authorities managed one cantonal waste collection centre financed by the cantonal fund for waste management (CFWM). This fund also financed cantonal awareness-raising campaigns regarding household waste sorting [10, 31] (see cognitive resources in Table 2).

Second, public and private actors operated various infrastructural resources (see Table 2) for the recovery of garden waste and food waste. The total treatment capacity of 28,800 t (see infrastructural resources in Table 2), however, remained insufficient with respect to the quantities of organic waste collected from households and enterprises in 2002 [10]. The main causes of this situation were civic opposition to the construction of a new composting centre [32] (see political support resources in Table 2) and technical problems at the composting and anaerobic digestion facility [10, 33]. Therefore, in 2002 the composting and anaerobic digestion facility transferred 600 t of untreated household organic waste to other Swiss facilities and, exceptionally, 700 t of it to the Genevan incineration plant, as shown by the grey arrows in Fig. 2.

Third, the private material recovery facilities were mainly in charge of packaging sorted waste fractions. They also dispatched them to recycling facilities in Switzerland or abroad. No recycling industry existed in Geneva [34] which is also the case today. It must be noted that the sorting-at-source practices used by Genevan municipalities, as well as the absence of a bag tax, enable them to obtain a low sorting reject level as underlined by Garcia et al. [34] and as pointed out by interviews with stakeholders. Therefore, the material systems shown in Figs. 2, 3 and 4 consider the sorting reject level from the material recovery facilities to be nil.

Fourth, an incineration plant operated by the public utility enterprise has ensured the safe treatment of combustible wastes, i.e. mixed waste, bulky waste and street cleaning waste, since 1966 [35]. An incineration tax is levied on all combustible waste delivered to the Genevan incineration plant (see financial resources in Table 2). It serves to finance the CFWM. In the framework of the landfill ban since 2000 [36] (see legal resources in Table 2), federal authorities granted a monopoly to the Swiss cantons and municipalities for the incineration of combustible waste. The monopoly was given through the definition of various supply zones [37], and consequently, Geneva has its own guaranteed supply zone (see market resources in Table 2) for combustible waste covering all the Genevan municipalities [31, 38]. However, this supply zone was too small compared to the capacity of the Genevan incineration plant (350,000 t/year, see infrastructural resources in Table 2). Therefore, Geneva decided to extend its guaranteed supply zone outside the neighbouring municipalities of Geneva [39] in the context of a long-term convention with an inter-municipal organisation. This convention allowed for the provision of bulky and mixed waste from 60 municipalities outside of Geneva (see market resources in Table 2). It enabled the provision of 26,244 t of bulky and mixed waste from outside of Geneva in 2002 (see Fig. 2). In addition, Geneva defined a

Table 2 Resources used by the household WM system in 2002, 2007 and 2013 by actors (*Fe* Federal authorities, *Ca* Genevan cantonal authorities, *Mu* Genevan municipalities, *Pe* Genevan public utility enterprise, *Pr* Genevan private actors, *Ea* public and private external actors)

Type	Description	2002	2007	2013	Act
Legal resource	Executive decision on the definition of a restricted commercial supply zone for combustible waste since 2008 [41, 42]			√	Ca
	Landfill ban in Switzerland [36]	√	√	√	Fe
Financial resource	Incineration tax, in CHF/t (and landfill tax, in CHF/t)	10	10	25 (2)	Ca
	Cantonal fund for waste management, revenues from the incineration tax and landfill tax in millions of CHF	3.28	2.98	6.15	Ca
	Municipal taxes	√	√	√	Mu
Infrastructural resource	Genevan incineration plant, capacity in kilotonnes/year	350	350	250	Pu
	Composting centres, composting and anaerobic digestion facility and composting along field edges, capacity in kilotonnes/year	28.8	33.95	33.95	Pe, Mu and Pr
	Cantonal waste collection centres				Ca and Pe
	In number of centres	1	3	3	
	Expenditures in millions of CHF	1.386	1.722	4.761	
	Selective collection of paper				Mu
	Kerbside collection, in number of municipalities	28	28	43	
	Collection points, in number of collection points	184	252	409	
	Selective collection of glass				Mu
	Kerbside collection, in number of municipalities	11	12	16	
	Collection points, in number of collection points	485	513	577	
	Selective collection of PET	197	213	287	Mu
	collection points, in number of collection points				
	Selective collection of aluminium and iron	278	286	330	Mu
	collection points, in number of collection points				
	Selective collection of garden waste				Mu
	In number of municipalities	36	40	38	
	Kerbside collection, in number of municipalities	20	23	23	
	Collection points, in number of collection points	41	89	76	
	Selective collection of food waste (with/without garden waste)				Mu
	in number of municipalities	19	19	23	
	Kerbside collection, in number of municipalities	17	17	18	
	Collection points, in number of collection points	75	111	257	
	Material recovery facilities	√	√	√	Pr
	Incineration plant in the Canton of Vaud [43]		√	√	Ea
Market resource	Commercial supply zone for combustible waste imports				Pe and Ea
	Punctual agreements with Swiss and French incineration plants for disposal surplus [44, 45]		√		
	Number of agreements with Swiss inter-municipal organisations [25, 39, 45] (in number of municipalities concerned)	3 (186)	2 (114)	0	
	Guaranteed supply zone for combustible waste imports: convention with neighbouring inter-municipal organisation, in number of municipalities concerned [38, 39, 46, 47]	60	60	17	Pe and Ea
Cognitive resource	Total expenditures for awareness-raising from the cantonal fund of waste management in millions of CHF by year	1.002	0.472	0.885	Ca
Time resource	Construction period for a new incineration plant in the Canton of Vaud [43, 48]	√			Ea
Political support resource	Petition against the implementation of a composting centre [32]	√			Pr
	Propositions of motion on the moratorium of waste imports from abroad [49–51]			√	Ca

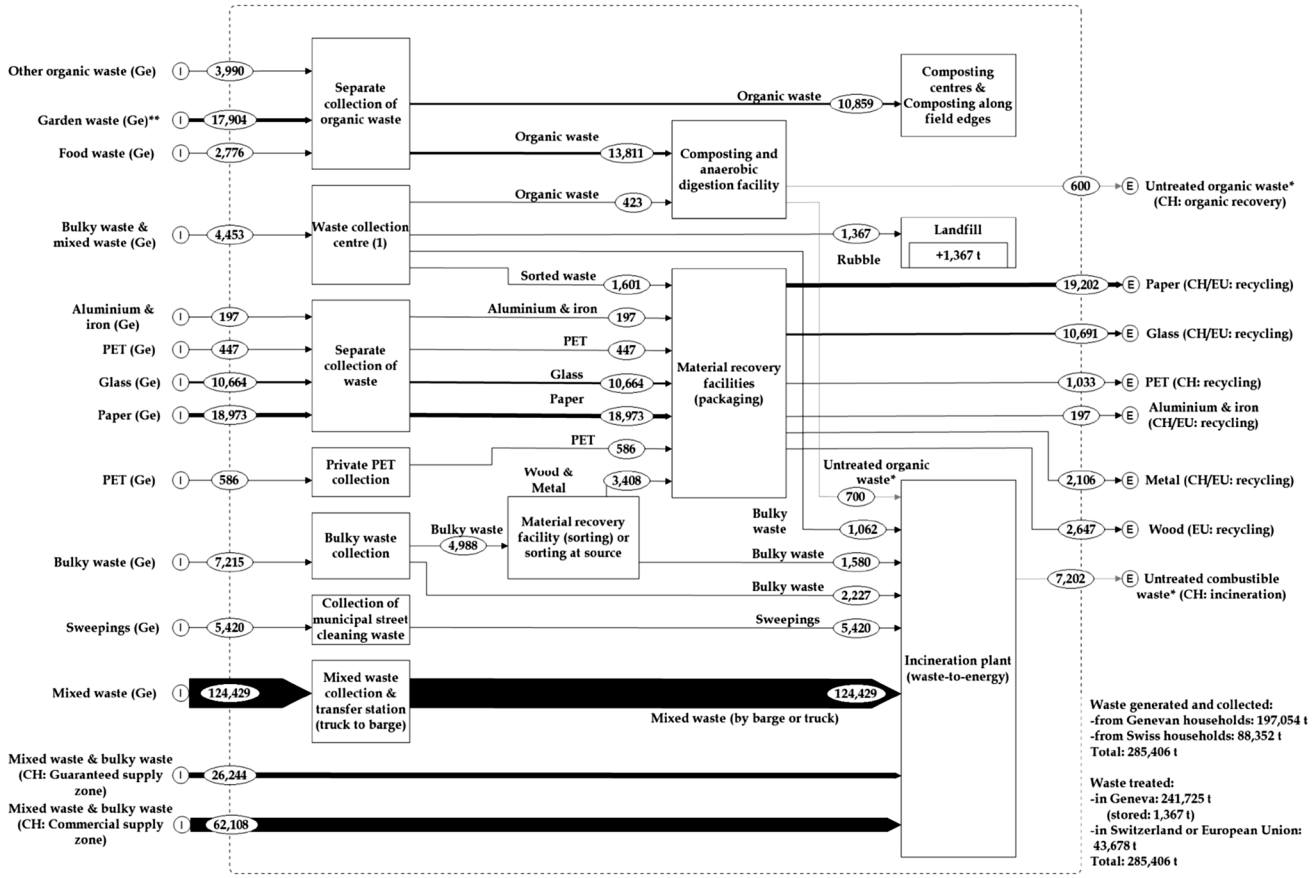

Fig. 2 Material system for the household WM of Geneva in 2002, in tonnes/year (t/y); *asterisk* waste received by the facility, but untreated and transferred to another facility for treatment; *double asterisks* with a non-quantifiable fraction of food waste; *Ge* Geneva, *CH* Switzerland, *EU* European Union Sources: [21, 22, 25]

commercial supply zone in the framework of inter-cantonal coordination for the incineration of Swiss urban waste [40]. In 2002, this zone covered 186 municipalities [39] outside of Geneva and was subject to three agreements among the Genevan incineration plant and different Swiss inter-municipal organisations [31, 38]. These agreements were signed to bridge the period of construction of an incineration plant in the neighbouring canton of Geneva, i.e. canton of Vaud (see time resources in Table 2). They enabled the provision of 62,108 t of bulky and mixed waste from outside of Geneva in 2002 (see Fig. 2). Besides, a fraction of untreated combustible waste, i.e. 7202 t as shown by the grey arrow in Fig. 2, was transferred to another incineration plant. This was due to maintenance work on the furnaces of the Genevan incineration plant [25].

Evolution of the household WM system and the resources used until 2013

This section focuses on the evolution of the household WM system in 2007 and 2013, as shown, respectively, by Figs. 3 and 4, on the basis of the resources used by the actors as given in Table 2.

The analysis will focus on two trends over the period 2002–2013: (1) the increase of waste sorted by the municipal separate collections and the cantonal waste collection centres, i.e. +28,022 t/year, +47%; and (2) the decrease of waste imports, i.e. by −80,371 t/year or −91% (see Figs. 2, 4).

First, the improvement in the municipal infrastructure for separate collection (see infrastructural resources in Table 2), e.g. new municipal collection points, an increase in municipalities' kerbside collection of paper, glass, garden and food waste, and the implementation of large-scale awareness-raising campaigns explain the strong growth in sorted waste observed over the period 2002–2007 [52], i.e. an increase of 13,866 t/year, +25% as illustrated by Figs. 2 and 3. In addition, the opening of two new cantonal waste collection centres increased the amount of waste sorted by these centres over the period 2002–2007, i.e. by +5677 t/year or +127%. Over the period 2007–2013, the cantonal and municipal authorities continued to reinforce their infrastructure for household waste sorting (see

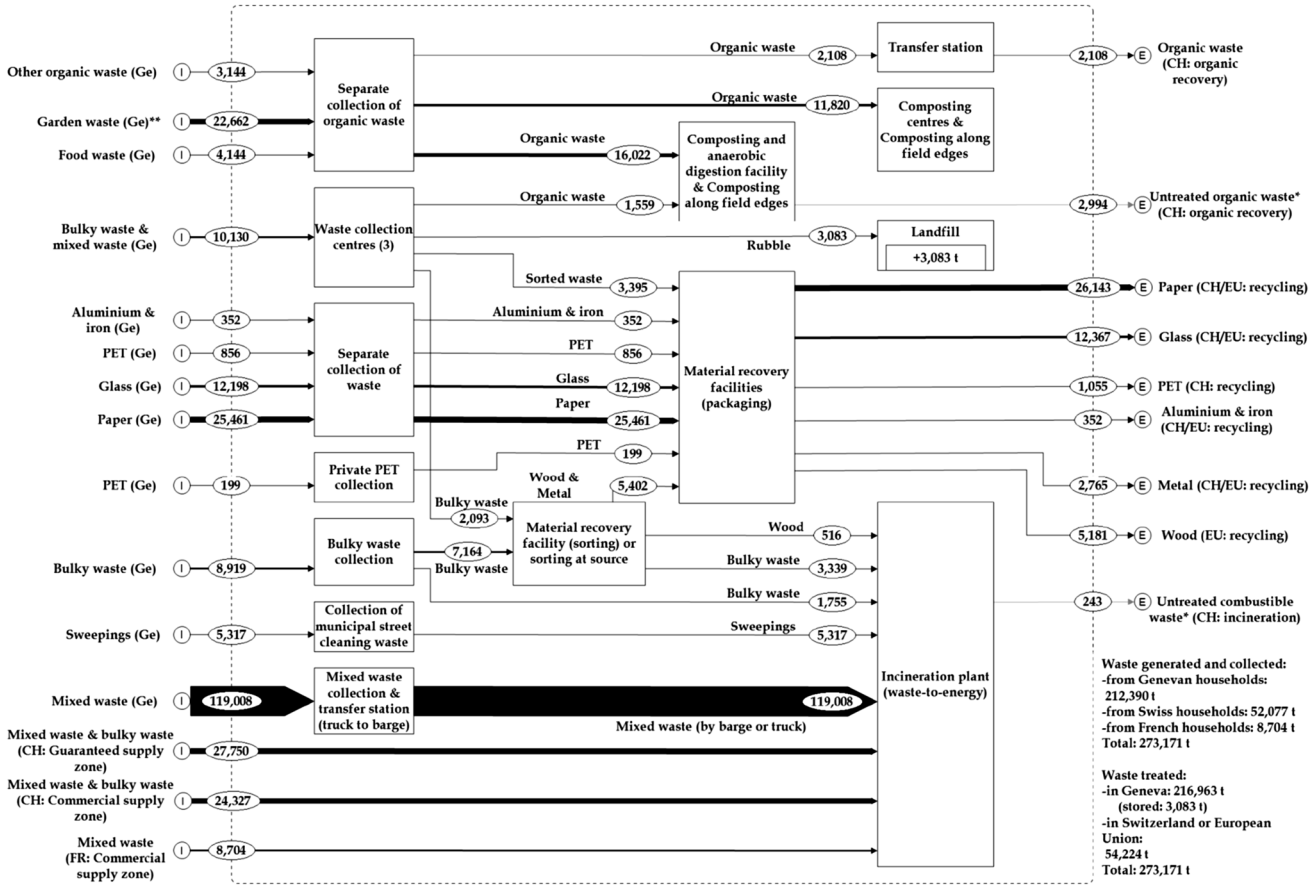

Fig. 3 Material system for the household WM of Geneva in 2007, in t/y; *asterisk* waste received by the facility, but untreated and transferred to another facility for treatment; *double asterisks* with a non-quantifiable fraction of food waste; *Ge* Geneva, *CH* Switzerland, *EU* European Union, *FR* France Sources: [21, 22, 24]

infrastructural resources in Table 2). This led to the growth of +8479 t/year of sorted waste, i.e. an increase of 11%, collected by the municipal separate collections and cantonal waste collection centres over the period 2007–2013, as observed by the cantonal authorities [12]. However, maturity with respect to household behaviour in terms of waste sorting explains the lowest growth concerning sorted wastes observed over the period 2007–2013 in comparison to the period of 2002–2013, as mentioned by the stakeholders interviewed. The reduction since 2006 in cantonal expenditures for raising awareness, i.e. −530,000 CHF between 2002 and 2007 and −117,000 CHF between 2002 and 2013 (see cognitive resources in Table 2), explains, to a lesser extent, this lowest growth. However, the current waste management plan [12] and the stakeholders interviewed underline the problems linked to food waste collection. Thus, only few Genevan municipalities have introduced separate collection for food waste, i.e. only 23 of 45 municipalities in 2013 (see infrastructural resources in Table 2). These problems are due to the current saturation and technical problems of the composting and the anaerobic digestion facility [10, 33]. The interview with stakeholders also underlines the poor design of plastic bags and kitchen bins for food waste collection which cause odours and hygiene problems for Genevan households. This explains why some of the Genevan households are resistant to food waste sorting.

Second, the opening of a new incineration plant in the neighbouring canton of Geneva in 2006 constitutes the main cause of the gradual reduction in waste imports from the commercial supply zone. This led to gradual ending of the agreements with the inter-municipal organisations linked to the commercial supply zone (see market resources in Table 2). Therefore, the waste imports from the commercial supply zones decreased by 29,077 t/year over the period 2002–2007 (as shown in Figs. 2, 3) and 25,050 t/year for the period 2007–2013 (as shown in Figs. 3, 4). This opening pushed the Genevan incineration plant to find other temporary sources of waste, such as French municipalities in 2007 [53], as illustrated in Fig. 3. Moreover, Genevan executive authorities limited the area of the commercial supply zone to Swiss cantons and French neighbouring municipalities in 2008 (see legal resources in Table 2). This decision resulted from public

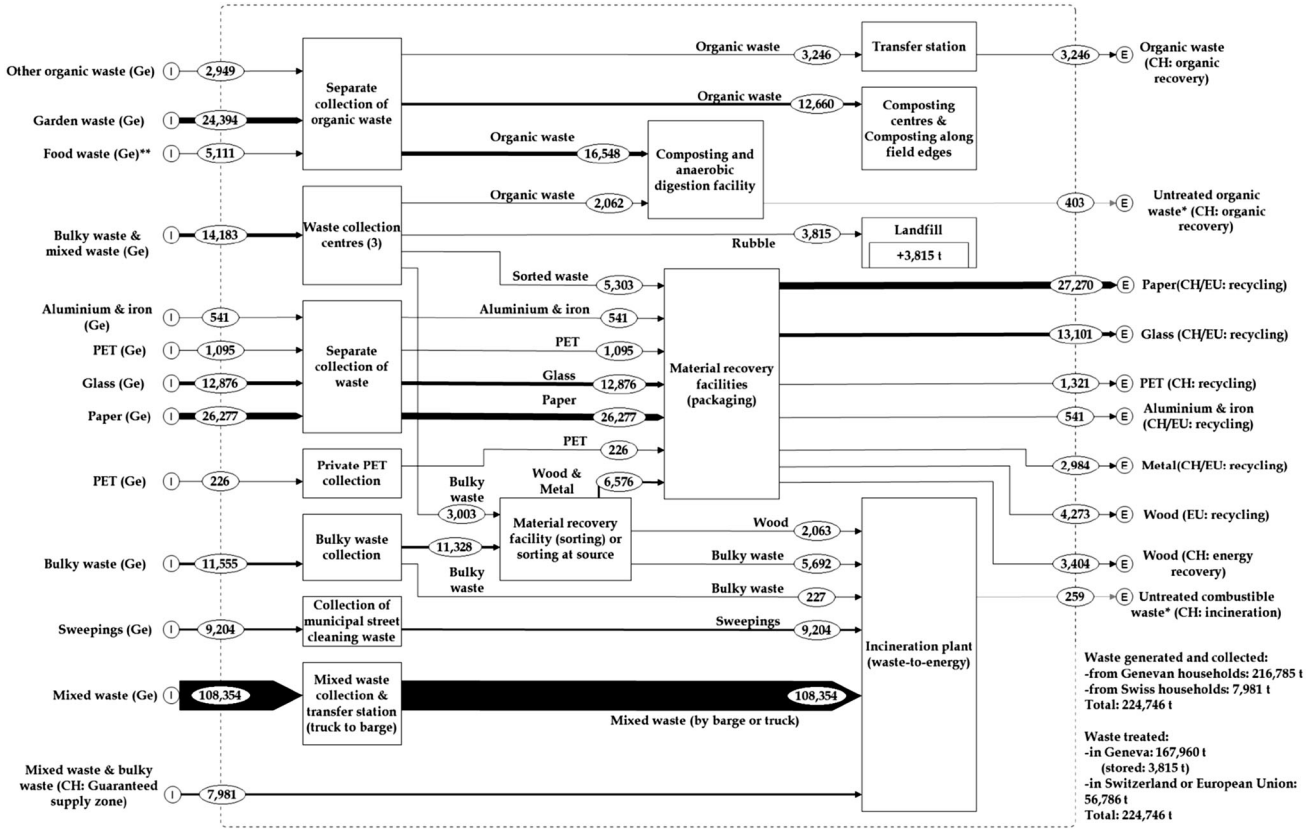

Fig. 4 Material system for the household WM of Geneva in 2013, in t/y, *asterisk* waste received by the facility, but untreated and transferred to another facility for treatment; *double asterisks* with a non-quantifiable fraction of food waste; *Ge* Geneva, *CH* Switzerland, *EU* European Union Sources: [21–23]

opposition to a project of waste imports from Italy (see political support resources in Table 2). It thus led to a reduction in treatment capacities in the Genevan incineration plant in 2010, i.e. from 350,000 to 250,000 t (see infrastructural resources in Table 2). In addition, a new convention between the neighbouring inter-municipal organisation of Geneva and the Genevan incineration plant caused a reduction in the guaranteed supply zone in 2013 [46, 54, 55] (see market resources in Table 2). Therefore, the waste imports from the guaranteed supply zone decreased by 71%, i.e. −19,769 t/year, between 2007 and 2013 as shown by Figs. 3 and 4.

Effects and lessons learned

The evolution of the household WM system and the resources used by public actors provoked two effects. First, the positive evolution of waste sorting enabled a significant decrease of recoverable waste fractions into Genevan bins, except for food waste, as illustrated in Table 3. In addition, the Genevan waste statistics [21] reveal an increase in the recovery rate, from 33% in 2002 to 45% in 2013, as illustrated by Fig. 5. They also show a decrease in waste incinerated per capita, from 302 kg per capita in 2002 to 240 kg per capita in 2013. These developments illustrate the desired impact of the infrastructural and persuasive instruments on household waste sorting. However, the problems identified previously regarding food waste collection demonstrate the importance of efficient infrastructural resources in favour of waste sorting.

Second, the reduction in incinerated waste, i.e. −90,249 t/year, −40%, combined with the increase in waste received by the cantonal waste collection centres, i.e. +9730 t/year, +219%, shown in Figs. 2 and 4 caused undesirable effects on the CFWM. On the revenue side, the continuous decrease in incinerated waste forced the cantonal authorities to raise the incineration tax between 2007 and 2013 and to introduce a landfill tax in 2013 (as illustrated in Tables 2, 4) to avoid revenue depletion. On the expenditure side, the increasing use of the cantonal waste collection centres caused a significant increase in operational costs from 1,390,000 CHF in 2002 to 4,760,000 CHF in 2013 as shown in Table 4. These two trends had provoked a capture of the CFWM budget since 2006 with a consumption of 74 to 84% of the budget over the period 2006–2013. This led to an unintended decrease in the

Table 3 Comparison of the waste fractions from mixed waste collection, i.e. the Genevan bin, and separated collections, i.e. recovered fractions, between 2002 and 2011, in kilogrammes per capita. Sources: [56–59]

	2002			2011		
	Genevan bin	Recovered fraction	Total	Genevan bin	Recovered fraction	Total
Paper and cardboard	54	45	99	31	56	87
Glass	24	25	49	16	27	43
PET, aluminium and iron	11	3	14	8	4	12
Food waste	71	7	78	80	9	89
Garden waste	18	51	69	5	53	58
Others	114	0	114	99	0	99
Total	292	131	423	239	149	388

Genevan population in 2002: 427,075 inhabitants; Genevan population in 2013: 466,918 inhabitants

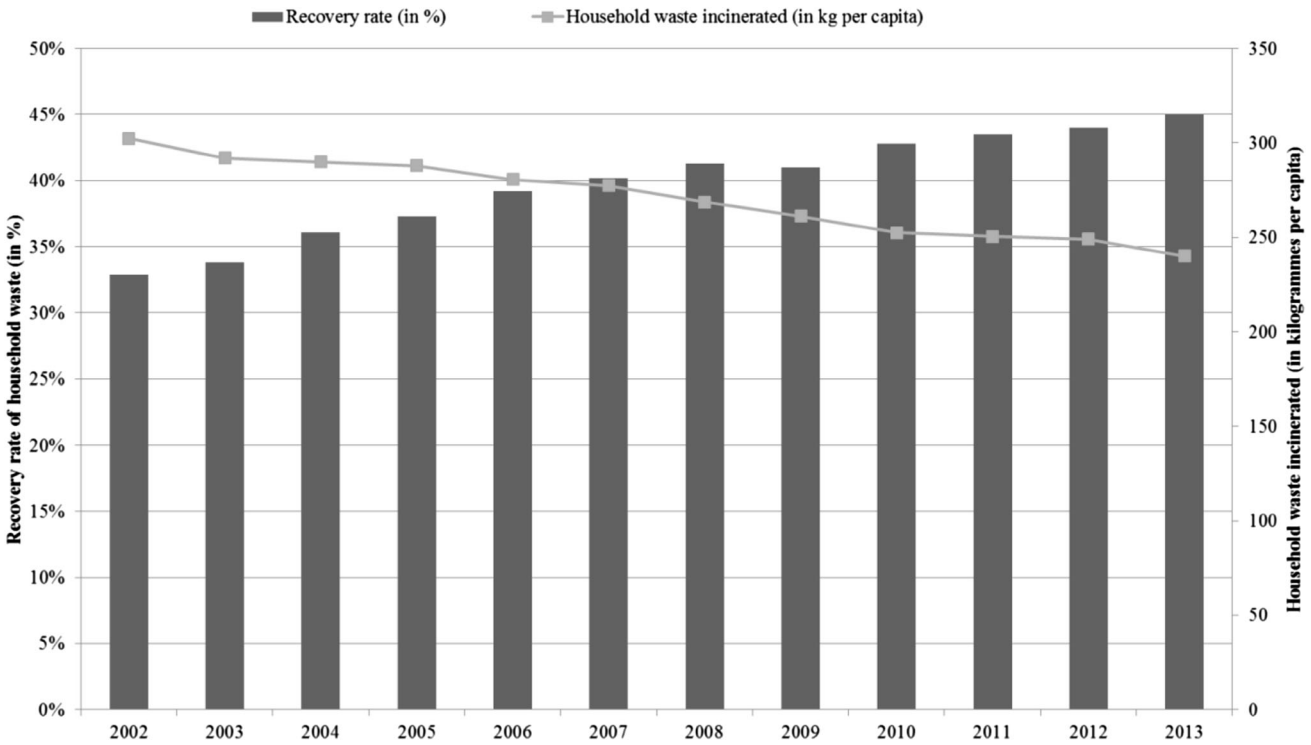

Fig. 5 Evolution of the recovery rate of household waste (*bars*) in %, and household waste incinerated (*curve*) over the period 2002–2013 in kilogrammes per capita. Source: [21]

expenditures for awareness-raising campaigns [9, 12, 52] from 1,000,000 CHF in 2002, to 470,000 CHF in 2007 and 880,000 CHF in 2013. Thus, the cantonal authorities recognised that the configuration had reached its limits. First, the incineration tax level almost reached the authorised legal limit of 30 CHF/t [60] and the limit of the Genevan municipalities' ability to pay, as was stressed during the interviews. Second, the cantonal authorities did not have the available budget to open a new cantonal waste collection centre as planned [12]. This undesired effect illustrates the inability of this financial mechanism to fund the annual operation of the sorting infrastructure. Thus, this financial mechanism necessarily induced an imbalance between revenues and expenses when the quantity of waste sorted simultaneously increased and that of waste incinerated decreased. In addition, this undesired effect illustrates that the evolution of the WM system can provoke feedback on the use of public resources by the Genevan authorities. This demonstrates the dynamic interaction over time between the resources used and the state of the WM system. This dynamic interaction must be taken into account in the assessment method.

Table 4 Revenues and expenditures of the CFWM (in millions of CHF) and taxation rates of waste incineration and waste landfill (in CHF per tonne), budget surpluses and deficits excluded. Sources: [9, 12]

Revenues	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total	3.28	3.12	3.05	3.07	3.27	2.98	3.47	5.08	4.81	4.94	4.89	6.15
Expenditures		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Cantonal waste collection centres		1.39	1.41	1.48	1.72	2.54	3.14	3.12	3.67	3.71	3.56	4.06	4.76
Awareness-raising		1.00	1.34	1.09	1.20	0.56	0.47	0.47	0.80	0.72	0.59	0.56	0.88
Other activities		0.87	0.48	0.54	0.41	0.29	0.27	0.30	0.50	0.49	0.26	0.21	0.55
Total budget		3.26	3.23	3.11	3.33	3.39	3.88	3.89	4.97	4.92	4.41	4.83	5.89
Taxation rate	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Incineration tax	10	10	10	10	10	10	13	21	21	21	21	25	
Landfill tax	–	–	–	–	–	–	–	–	–	–	–	2	

Conclusions

This case study presents an assessment of household WM in Geneva. The mobilisation of public resources by cantonal and municipal authorities has led to a desired growth in waste sorted and a desired decrease in Genevan waste incinerated over the period 2002–2013. Moreover, these previous trends combined with the strong decrease in imported waste led to an increase in the rate of the incineration tax to support the growing operating costs of the cantonal waste collection centres. This also induced the monopolisation by waste collection centres of the available funds in the CFWM budget at the expense of raising awareness. This monopolisation thus caused a decrease in the cantonal budget for raising awareness.

These findings allow to derive two recommendations regarding waste sorting in the framework of waste policy. First, a policy instrument mix based on infrastructural and persuasive instruments constitutes a relevant approach for household waste sorting. Second, the use of a financial mechanism based on a "disposal tax", i.e. an incineration tax and a landfill tax, does not constitute a sustainable approach to finance the annual operating costs of the sorting infrastructure. A financial mechanism based on the quantities of waste generated or on a constant revenue source, e.g. a municipal tax, seems a more stable approach for financing the annual operating costs for waste sorting. Therefore, further research should be carried out to find other sustainable solutions.

The combination of policy analysis and material system analysis allows a joint analysis of the evolution of the resources used by public and private actors and the state of the WM system. For this case study, this method made it possible to link waste policy to the evolution of the waste flows over the period of 2002–2013. It provides information on how the modification of the state of a WM system affects the resources used by actors. Further research should be conducted to take into account the dynamic interactions between the resources used by actors and the state of the WM system. Moreover, other case studies should be analysed to evaluate the flexibility and usefulness of this new assessment approach in the field of WM and resource management.

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Compliance with ethical standards

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References

1. Zurbrügg C, Caniato M, Vaccari M (2014) How assessment methods can support solid waste management in developing countries—a critical review. Sustainability 6:545–570. doi:10.3390/su6020545
2. Brunner PH, Rechberger H (2004) Practical handbook of material flow analysis. CRC/Lewis, Boca Raton
3. Moll S, Fernia A (2005) Use of MFA-related family of tools in environmental policy-making. European Environment Agency, Copenhagen
4. OECD (2008) Measuring material flows and resource productivity—synthesis report. Organisation for Economic Co-operation and Development, Paris

5. Howlett M, Kim J, Weaver P (2006) Assessing instrument mixes through program- and agency-level data: methodological issues in contemporary implementation research. Rev Policy Res 23:129–151. doi:10.1111/j.1541-1338.2006.00189.x
6. Knoepfel P, Larrue C, Varone F, Hill M (2011) Public policy analysis. Policy Press, Bristol
7. Larrue C (2000) Analyser les politiques publiques d'environnement. Harmattan, Paris
8. RCG (2003) Cantonal concept of waste management 2002 (in French). Republic and Canton of Geneva (RCG): Cantonal service of waste management, Geneva, Switzerland
9. RCG (2009) Waste management plan of the Canton of Geneva 2009–2012 (in French). Republic and Canton of Geneva (RCG): Service of geology, soils and waste, Geneva, Switzerland
10. RCG (2003) Waste management plan of the Canton of Geneva 2003–2007 (in French). Republic and Canton of Geneva (RCG): Cantonal service of waste management, Geneva, Switzerland
11. Parilla J, Trujillo LJ, Berube A, Ran T (2015) Global MetroMonitor 2014: an uncertain recovery. The Brookings institution, Metropolitan policy program, USA
12. RCG (2015) Waste management plan of the Canton of Geneva 2014–2017 (in French). Republic and Canton of Geneva (RCG): Service of geology, soils and waste, Geneva, Switzerland
13. RCG (2015) State of the population of the Canton of Geneva in 2014 (in French). Republic and Canton of Geneva (RCG): Cantonal office of statistic, Geneva, Switzerland
14. RCG (2008) Twenty years of economic development in the Canton of Geneva (in French). Republic and Canton of Geneva (RCG): Cantonal office of statistic, Geneva, Switzerland
15. Klok PJ (1995) A classification of Instruments for environmental policy. In: Dente PB (ed) Environmental policy in search of new instruments. Springer, Netherlands, pp 21–36
16. Weiss CH (1998) Evaluation: methods for studying programs and policies, 2nd edn. Prentice Hall, Upper Saddle River
17. Mickwitz P (2013) Policy evaluation. Environmental Policy in the EU: actors, institutions and processes. Routledge, London, pp 267–286
18. UNAIDS (2010) An introduction to triangulation. UNAIDS Monitoring and Evaluation Fundamentals, Geneva
19. Bailey KD (2007) Methods of social research, 4th edn. Free Press, New York
20. Goodwin J (2012) SAGE secondary data analysis. SAGE, Los Angeles
21. RCG (2015) Wastes: statistics (in French). Republic and Canton of Geneva (RCG): Service of geology, soils and waste. http://ge.ch/dechets/publications/statistiques. Accessed 4 Mar 2015
22. RCG (2015) Cantonal statistics: wastes (in French). Republic and Canton of Geneva (RCG): Cantonal office of statistics. http://www.ge.ch/statistique/domaines/02/02_02/tableaux.asp#7. Accessed 4 Mar 2015
23. SIG (2013) Operation report of the incineration plant of Cheneviers 2012 (in French). Services industriels de Genève, Geneva, Switzerland
24. SIG (2009) Operation report of the incineration plant of Cheneviers 2008 (in French). Services industriels de Genève, Geneva, Switzerland
25. SIG (2006) Operation report of the incineration plant of Cheneviers 2005 (in French). Services industriels de Genève, Geneva, Switzerland
26. Beguin H (1998) Analyse mathématique. In: Bailly A (ed) Les concepts de la géographie humaine, 4. éd. rev. et augm. Colin, Paris, pp 266–275
27. Baccini P, Brunner PH (2012) Metabolism of the anthroposphere: analysis, evaluation, design, 2nd edn. MIT Press, Cambridge
28. Meylan G, Seidl R, Spoerri A (2013) Transitions of municipal solid waste management. Part I: scenarios of Swiss waste glass-packaging disposal. Resour Conserv Recycl 74:8–19. doi:10.1016/j.resconrec.2013.02.011
29. Matsubae-Yokoyama K, Kubo H, Nakajima K, Nagasaka T (2009) A material flow analysis of phosphorus in Japan. J Ind Ecol 13:687–705. doi:10.1111/j.1530-9290.2009.00162.x
30. Swiss Confederation (2002) Waste Statistics 2000. With 2001 data on the planning of incineration plants (in French). Swiss Confederation: Federal Office for the Environment, Bern
31. RCG (1999) Waste management plan of the Canton of Geneva 1998–2002 (in French). Republic and Canton of Geneva (RCG): Department of the interior, agriculture, environment and energy, Geneva, Switzerland
32. RCG (2000) Report of the Committee on the Environment and Agriculture to study the petition regarding the future composting center Arve-Lac in Vandoeuvres (in French). Republic and Canton of Geneva (RCG): Secretariat of the Grand Council of Geneva, Geneva, Switzerland
33. RCG (2005) Waste management plan of the Canton of Geneva 2003–2007: modification of the chapter on compost (in French). Republic and Canton of Geneva (RCG): Cantonal service of waste management, Geneva, Switzerland
34. Garcia X, Cornaglia L, Dubrova-Froidevaux I (2014) Comparative study on the methods of collection and recovery of recyclable waste (in French). Grand Genève, Agglomération franco-valdo-genvoise, Geneva, Switzerland
35. RCG (2000) Cantonal concept of environmental protection. Assessment of the state of the environment (in French). Republic and Canton of Geneva (RCG): Department of the interior, agriculture, environment and energy, Geneva, Switzerland
36. Swiss Confederation (1990) Ordinance on waste treatment. Swiss Confederation: Swiss Federal Chancellery, Bern
37. Swiss Confederation (1983) Environmental Protection Act. Swiss Confederation: Swiss Federal Chancellery, Bern
38. RCG (2000) Operation report of the incineration plant of Cheneviers 1999 (in French). Republic and Canton of Geneva (RCG): Department of the interior, agriculture, environment and energy, Geneva, Switzerland
39. Canton of Vaud (2004) Waste management plan 2004 (in French). Canton of Vaud, Department of security and environment, Lausanne, Switzerland
40. Swiss Confederation (1997) Inter-cantonal cooperation is implemented: Coordination of the incineration plants in western Switzerland (in French). Swiss Confederation: Federal Office for the Environment, Bern
41. RCG (2008) Press release of March 11, 2008: Imports of waste in Geneva (in French). Republic and Canton of Geneva (RCG): Council of State, Geneva, Switzerland
42. RCG (2008) Briefing of May 21, 2008: No to the import of foreign waste (in French). Republic and Canton of Geneva (RCG): Council of State, Geneva, Switzerland
43. TRIDEL (2013) Waste to energy facility, management report 2012 (in French). TRIDEL SA, Canton of Vaud, Switzerland
44. Massard G, Gonseth A, Darne JC, Fevre J (2012) Management on the combustible waste on the territory of France-Vaud-Geneva conurbation (in French). Agglomération franco-valdo-genevoise, Geneva, Switzerland
45. SIG (2008) Operation report of the incineration plant of Cheneviers 2007 (in French). Services industriels de Genève, Geneva, Switzerland
46. Canton of Vaud (2015) Waste management plan 2014 (in French). Canton of Vaud, Department of security and environment, Lausanne, Switzerland
47. SADEC (2012) General Assembly of June 27 2012 in Gimel, Activity Report of the Administrative Council for the year 2011 (in French). Société Anonyme pour le traitement des Déchets de la Côte (SADEC), Canton of Vaud, Switzerland

48. Canton of Vaud (2001) Bulletin of the meetings of the Great Council of Vaud No. 3 session Monday afternoon May 7, 2001 (in French). Canton of Vaud, Grand Council, Lausanne, Switzerland
49. RCG (2008) Proposed motion M 1820, prevention is better than cure: for a coherent waste policy (in French). Republic and Canton of Geneva (RCG): Secretariat of the Grand Council of Geneva, Geneva, Switzerland
50. RCG (2008) Proposed Motion M 1811, for a moratorium on the import of foreign waste and an extensive waste management policy at the France-Vaud-Geneva conurbation (in French). Republic and Canton of Geneva (RCG): Secretariat of the Grand Council of Geneva, Geneva, Switzerland
51. RCG (2008) Proposed Motion M 1812, for clarification of the waste policy in Geneva and the region (in French). Republic and Canton of Geneva (RCG): Secretariat of the Grand Council of Geneva, Geneva, Switzerland
52. RCG (2011) Report of the State Council to the Grand Council on Motion M1890, related to motions 1811, 1812, 1813 and 1820 (in French). Republic and Canton of Geneva (RCG): Secretariat of the Grand Council of Geneva, Geneva, Switzerland
53. SIG (2010) Operation report of the incineration plant of Cheneviers 2009 (in French). Services industriels de Genève, Geneva, Switzerland
54. SADEC (2014) General Assembly of June 5 2014 in Tartegnin, Activity Report of the Administrative Council for the year 2013 (in French). Société Anonyme pour le traitement des Déchets de la Côte (SADEC), Canton of Vaud, Switzerland
55. SIG (2014) Operation report of the incineration plant of Cheneviers 2013 (in French). Services industriels de Genève, Geneva, Switzerland
56. RCG (2004) Waste inventory 2003 in the Canton of Geneva: Municipal urban waste: State of selective collection (in French). Republic and Canton of Geneva (RCG): Cantonal service of waste management, Geneva, Switzerland
57. RCG (2012) Composition of household waste in the canton of Geneva: 2011 Survey (in French). Republic and Canton of Geneva (RCG): Service of geology, soils and waste, Geneva, Switzerland
58. Villegas A (2013) The analysis of the composition of Geneva's household waste for planning purposes. ISWA World Congress 2013, Vienna, Austria
59. RCG (2012) Waste inventory 2011 in the Canton of Geneva: Municipal urban waste: State of selective collection (in French). Republic and Canton of Geneva (RCG): Service of geology, soils and waste, Geneva, Switzerland
60. RCG (1999) Regulation Implementing of the Waste Management act of July 28 1999 (in French). Republic and Canton of Geneva (RCG), Geneva, Switzerland