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Review

Solid waste management challenges for cities in developing countries

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ABSTRACT

Solid waste management is a challenge for the cities' authorities in developing countries mainly due to the increasing generation of waste, the burden posed on the municipal budget as a result of the high costs associated to its management, the lack of understanding over a diversity of factors that affect the different stages of waste management and linkages necessary to enable the entire handling system functioning. An analysis of literature on the work done and reported mainly in publications from 2005 to 2011, related to waste management in developing countries, showed that few articles give quantitative information. The analysis was conducted in two of the major scientific journals, Waste Management Journal and Waste Management and Research. The objective of this research was to determine the stakeholders' action/behavior that have a role in the waste management process and to analyze influential factors on the system, in more than thirty urban areas in 22 developing countries in 4 continents. A combination of methods was used in this study in order to assess the stakeholders and the factors influencing the performance of waste management in the cities. Data was collected from scientific literature, existing data bases, observations made during visits to urban areas, structured interviews with relevant professionals, exercises provided to participants in workshops and a questionnaire applied to stakeholders. Descriptive and inferential statistic methods were used to draw conclusions. The outcomes of the research are a comprehensive list of stakeholders that are relevant in the waste management systems and a set of factors that reveal the most important causes for the systems' failure. The information provided is very useful when planning, changing or implementing waste management systems in cities.

1. Introduction

Increasing population levels, booming economy, rapid urbanization and the rise in community living standards have greatly accelerated the municipal solid waste generation rate in developing countries (Minghua et al., 2009). Municipalities, usually responsible for waste management in the cities, have the challenge to provide an effective and efficient system to the inhabitants. However, they often face problems beyond the ability of the municipal authority to tackle (Sujauddin et al., 2008) mainly due to lack of organization, financial resources, complexity and system multi dimensionality (Burntley, 2007).

In the last years, a large number of research studies have been undertaken to determine influential factors affecting waste management systems in cities in developing countries. An examination of the publications from 2005 to 2011, from two of the major scientific journals, related to waste management, Waste Management Journal and Waste Management and Research, 37 showed information related to factors affecting the system. Surprisingly, few gave quantitative information.

This research has the aim to determine the stakeholders that have an interest in the waste management system of cities under study and the factors that influence the performance of the system in three continents, from more than thirty urban areas in twenty two developing countries.

2. Theoretical framework

Integrated Sustainable Waste Management (ISWM) Model is a model that allows studies of the complex and multi dimensional systems in an integral way. The model was developed by WASTE advisers on urban environment and development (WASTE, 2004) and partners or organizations working in developing countries in the mid-1980s and further developed by the Collaborative Working Group (CWG) on solid waste management in the mid-1990's (Anschütz et al., 2004).

The model acknowledges the importance of three dimensions when analyzing, developing or changing a waste management system. The dimensions are: the stakeholders that have an interest in solid waste management the elements or stages of the movement

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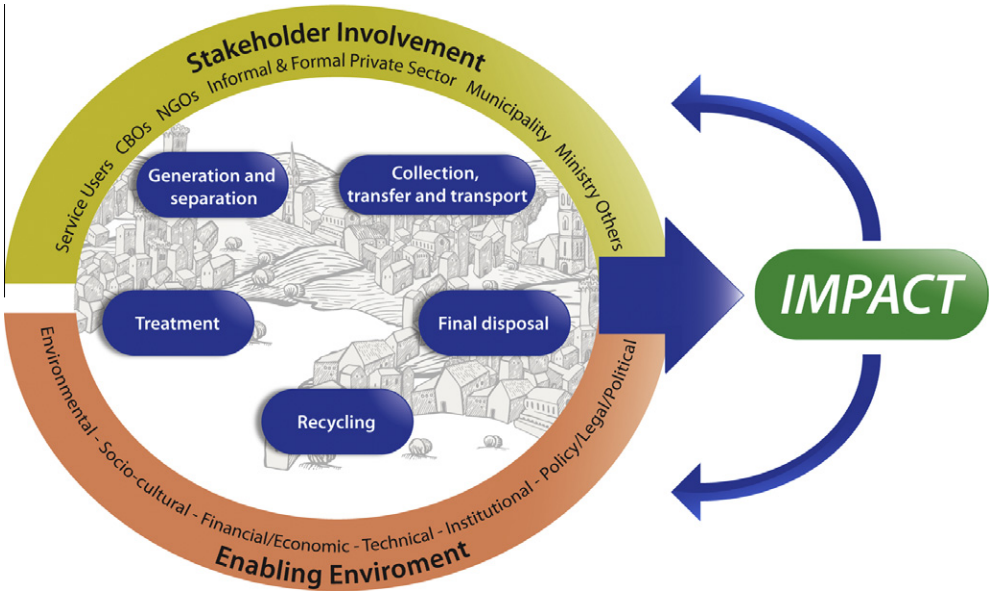

Fig. 1. The integrated sustainable waste management model (WASTE, 2004; adapted from ISSOWAMA Consortium, 2009).

or flow of materials from the generation points towards treatment and final disposal and the aspects or "lenses" through which the system is analyzed (Müller et al., 2002; Müller and Scheinberg, 2002; Zurbrügg et al., 2005; Zuilen, 2006; ISSOWAMA Consortium, 2009; Wilson et al., 2009; Scheinberg et al., 2010, 2011).

The present work is set within an adapted ISWM framework (Fig. 1). Especially, it focuses on investigating the stakeholders' action/behavior and factors that influence the elements of the city's waste management system and the technical but also environmental, socio cultural, legal, institutional and economic linkages present to enable the overall system to functioning.

To facilitate the analysis of information, existing elements of the waste management systems are described in terms of waste generation and separation, collection, transfer and transport, treatment, recycling and final disposal.

3. Literature review

Past research has identified the stakeholders or people or organizations that may have an interest in adequate waste management. The stakeholders reported are: national and local government (Shekdar, 2009); municipal authorities; city corporations; non-governmental organizations (NGO's); households (Sujauddin et al., 2008); private contractors; Ministries of Health; Environment, Economy and Finance (Geng et al., 2009) and recycling companies (Tai et al., 2011).

Some scholars have identified factors influencing the elements of the waste management systems. According to Sujauddin et al. (2008) the generation of waste is influenced by family size, their education level and the monthly income. Households attitudes related to separation of waste are affected by the active support and investment of a real estate company, community residential committees' involvement for public participation (Zhuang et al., 2008) and fee for collection service based on the waste volume or weight (Scheinberg, 2011). Gender, peer influence, land size, location of household and membership of environmental organization explain household waste utilization and separation behavior (Ekere et al., 2009).

It has been reported that collection, transfer and transport practices are affected by improper bin collection systems, poor route planning, lack of information about collection schedule (Hazra and Goel, 2009), insufficient infrastructure (Moghadam et al., 2009), poor roads and number of vehicles for waste collection (Henry et al., 2006). Organizing the informal sector and promoting micro-enterprises were mentioned by Sharholy et al. (2008) as effective ways of extending affordable waste collection services.

Lack of knowledge of treatment systems by authorities is reported as one factor affecting the treatment of waste (Chung and Lo, 2008).

Tadesse et al. (2008) analyzed the factors that influence household waste disposal decision making. Results showed that the supply of waste facilities significantly affects waste disposal choice. Inadequate supply of waste containers and longer distance to these containers increase the probability of waste dumping in open areas and roadsides relative to the use of communal containers. Insufficient financial resources limiting the safe disposal of waste in well equipped and engineered landfills and absence of legislation are mentioned by Pokhrel and Viraraghavan (2005).

In relation to the pricing for disposal Scheinberg (2011), analyzing the data from "Solid Waste Management in the World's Cities" (Scheinberg et al., 2010), notes that there are indications that high rates of recovery are associated with tipping fees at the disposal site. High disposal pricing has the effect of more recovery of waste generated, that goes to the value chains or beneficial reuse of waste.

In relation to recycling Gonzalez-Torre and Adenso-Diaz (2005) reported that social influences, altruistic and regulatory factors are some of the reasons why certain communities develop strong recycling habits. The authors also showed that people who frequently go to the bins to dispose of general refuse are more likely to recycle some product at home, and in most cases, as the distance to the recycling bins decreases, the number of fractions that citizens separate and collect at home increases. Minghua et al. (2009) stated that in order to increase recycling rates, the government should encourage markets for recycled materials and increasing professionalism in recycling companies. Other factors mentioned by other scholars are financial support for recycling projects and infrastructures (Nissim et al., 2005), recycling companies in the country (Henry et al., 2006), drop-off and buy back centers (Matete and Trois, 2008) and organization of the informal sector (Sharholy et al., 2008).

Waste management is also affected by the aspects or enabling factors that facilitate the performance of the system. They are: technical, environmental, financial, socio-cultural, institutional and legal.

Literature suggests that technical factors influencing the system are related to lack of technical skills among personnel within municipalities and government authorities (Hazra and Goel, 2009), deficient infrastructure (Moghadam et al., 2009), poor roads and vehicles (Henry et al., 2006), insufficient technologies and reliable data (Mrayyan and Hamdi, 2006).

Matete and Trois (2008) and Asase et al. (2009) respectively suggested that the factors affecting the environmental aspect of solid waste management in developing countries are the lack of environmental control systems and evaluation of the real impacts. Ekere et al. (2009) proposed that the involvement of the population in active environmental organizations is necessary to have better systems.

Municipalities have failed to manage solid waste due to financial factors. The huge expenditure needed to provide the service (Sharholy et al., 2007), the absence of financial support, limited resources, the unwillingness of the users to pay for the service (Sujauddin et al., 2008) and lack of proper use of economic instruments have hampered the delivery of proper waste management services. Sharholy et al. (2008) indicated that the involvement of the private sector is a factor that could improve the efficiency of the system.

It is generally regarded that waste management is the sole duty and responsibility of local authorities, and that the public is not expected to contribute (Vidanaarachchi et al., 2006). The operational efficiency of solid waste management depends upon the active participation of both the municipal agency and the citizens, therefore, socio cultural aspects mentioned by some scholars include people participating in decision making (Sharholy et al., 2008), community awareness and societal apathy for contributing in solutions (Moghadam et al., 2009).

Management deficiencies are often observed in the municipalities. Some researchers that have investigated the institutional factors that affect the system have come to the conclusion that local waste management authorities have a lack of organizational capacities (leadership) and professional knowledge. Besides they concluded that the information available is very scanty from the public domain (Chung and Lo, 2008). The extremely limited information is not complete or is scattered around various agencies concerned, therefore, it is extremely difficult to gain an insight into the complex problem of municipal solid waste management (Seng et al., 2010).

Waste workers are associated to low social status (Vidanaarachchi et al., 2006) situation that gives as a result low motivation among the solid waste employees. Politicians give low priority to solid waste compared to other municipal activities (Moghadam et al., 2009) with the end result of limited trained and skilled personnel in the municipalities (Sharholy et al., 2008). Positive factors mentioned that improve the system are support from municipal authorities (Zurbrügg et al., 2005) and strategic plans for waste management that allows monitoring and evaluating annually the system (Asase et al., 2009).

Researchers have documented how an adequate legal framework contributes positively to the development of the integrated waste management system (Asase et al., 2009) while the absence of satisfactory policies (Mrayyan and Hamdi, 2006) and weak regulations (Seng et al., 2010) are detrimental to it.

4. Research methodology

The review of the literature provided an overview of reported stakeholders and factors affecting waste management systems. Data on country performance indicators were gathered from databases. They were: public health (perinatal mortality, adult mortality, life expectancy at birth and healthy life expectancy at birth (WHO, 2010a, 2010b, 2010c, 2010d; USEPA, 2010), economy (Gross Domestic Product/capita) (WB, 2010), and environment (ecological footprint/capita (Global Footprint Network, 2010), CO_2-emission/capita (UN, 2007). In addition, the following country characterization parameters were selected (persons/km^2, % urban population) (CIA, 2010).

In addition, information was gathered from more than thirty urban areas visited, in some cases for more than one occasion, in twenty two developing countries in three continents (Table 1). Data collection has been supported by different contributors in those cities during visits made by the first author during the period 1985–2011.

Furthermore, information was collected by means of exercises provided to participants during workshops including questions about the stakeholders and the state of the solid waste management system in the city in relation to the elements, the aspects and the problems associated with them. Waste management practices were followed by on-site visits of households, hospitals, offices and schools, construction sites, health care centers, agricultural and commercial areas. The following characteristics were noted: collection and transportation systems, waste treatment procedures, identification of materials for reuse and recycling and final disposal facilities. The findings were presented, analyzed and validated with relevant stakeholders from the visited cities.

The parameters found by the first author's visits to the cities allowed creating a questionnaire (Appendix A) that has been used to systematize gathered information before 2009 and to obtain new data about waste management systems in cities up to 2011. It contains 122 questions of which 74 are measured on a five-point Likert-type scale with anchors ranging from never, none, very bad (1) to always, all, excellent (5) (Matell and Jacoby, 1971), as values of actual measurements (5 questions), binary scale (Yes/No) (22 questions) (Ekere et al., 2009) and general information (21 questions).The literature review from 2005 to 2011 allowed to validate some of the parameters used in the tool as well as to introduce others not reported during the reviewed years.

Prior to data collection the questionnaire was pre-tested for ease of understanding and content validity. A group of stakeholders from 8 municipalities (3 in South Africa, 2 in Indonesia, 1 in Peru, 1 in Kenya, 1 in Philippines) in 5 different countries in 3 continents were asked to criticize the questionnaire for ambiguity, clarity and appropriateness of the items used to operationalize each construct. The respondents were also requested to assess the extent to which the factors sufficiently addressed the topics investigated. Based on the feedback received, the instrument was modified accordingly and used to collect information about the state of waste management in the cities.

Due to the amount of information, constructs were prepared from the raw data.

(i) Household separation as follows: summing up the points provided by the respondent on the five-point variables on extend of waste separation at: household, business, plastic, paper, metal, glass, organic materials, battery, electric and electronic municipality level.
(ii) Sophistication of waste collection system as follows: 1 = No organized collection of solid waste; 2 = Manpower only (Wheel-barrow and/or hand trolley and/or rickshaw and/or tricycle); 3 = Manpower and draught animal; 4 = Motorized transport (Motorcycle and/or tractor and/or truck) but no contractor used; and 5 = Motorized transport (Motorcycle and/or tractor and/or truck) and compactor used.
(iii) Environmental awareness campaigns as follows: one point for each positive answer to the nominal variables: environmental awareness campaigns supported by municipality; re-use awareness campaigns in the municipality; presence

Table 1
Urban areas visited, country Gross Domestic Product (GDP), waste generation rate (kg/capita/day) and solid-waste origins studied; 1 = household; 2 = offices, schools; 3 = construction; 4 = health care; 5 = agriculture; 6 = industry; and 7 = shops.

Continent	Country	GDP (US$)	Year of study	City	Waste origin arriving at the official disposal site	Waste generation rate (kg/capita/day)
Africa	Ethiopia	344	2009	Addis Ababa	1,2,4,6,7	0.32
	Kenya	738	2009	Nakuru	1,2,3,4,5,6,7	0.50
	Malawi	326	2009	Lilongwe	1	0.50
	South-Africa	5786	2009	Pretoria	1,2,3,4,7	0.65
	South-Africa	5786	2009	Langeberg	1,3,4,5,6,7	0.65
	South-Africa	5786	2009	Emfuleni	1,3,6	0.60
	Tanzania	509	2010	Dar es Salam	1,2,4,5,6,7	0.50
	Zambia	985	2010	Lusaka	1,2,3,4,6,7	0.37
Asia	Bangladesh	551	2007, 2008, 2009	Gazipur	1,4	0.25
	Bhutan	1805	2010	Thimphu	1,2,3,7	0.54
	China	3744	2010	Beijing	1,3,4,7	0.80
	India	9232	2010	Doddaballapur	1,2,3,6,7	0.28
	Indonesia	2349	2009, 2010	Banda Aceh	1,4	0.90
	Indonesia	2349	2009, 2010	Ambon	1,4	0,90
	Indonesia	2349	2010	Jogjakarta	1,2,5,7	0.90
	Nepal	364	2007	Kathmandu	1,2,6,7	0.35
	Pakistan	495	1995	Lahore	1,2,6,7	0.84
	Philippines	1995	2009	Quezon City	1,2,3,4,7	0.67
	Sri Lanka	2068	2010	Balangoda	1,2,3,4,6,7	0.83
	Sri Lanka	2068	2010	Hambantota	1,2,3,4,7	0.81
	Thailand	4043	2009, 2010	Bangkok	1,2,3,4,6,7	1.10
	Turkey	8215	2010	Kutahya	1,2,4,6,7	0.60
	Turkey	8215	2010	Bitlis	1,2,3,4,5,6,7	0.90
	Turkey	8215	2010	Amasya	1,2,4,7	1,20
Central & South America	Costa Rica	4084	1985, 1995	Cartago	1,2,3,4,5,7	0.7-0.8
	Costa Rica	6386	2011	San José	1, 2, 3, 4, 6, 7	1.10
	Costa Rica	3370	1991	Talamanca	1,7	0.30
	Costa Rica	4084	1992, 1995	Tarcoles	1,7	0.30-0.50
	Costa Rica	5529	2001	Tuis	1,7	0.30
	Ecuador	1771	1995	Pillaro	1,7	0.50
	Ecuador	1771	1995	El Carmen de los Colorados	1,7	0.50
	Nicaragua	1069	2008, 2009, 2010	Managua	1,2,3,4,5,6,7	0.48
	Nicaragua	1069	2009, 2010	Masaya	1,2,4,7	0.40
	Peru	4447	2008, 2009, 2010	Cañete	1,2,3,4,5,6,7	0.47
	Suriname	5888	2008, 2009	Paramaribo	1,7	0.47
	Suriname	5888	2008	Asidonhopo	–*	0.28

* Absence official disposal site.

of environmental campaigns in the city; public awareness campaigns for waste management plus the points provided by the respondent on the five-point variables: reduction campaigns in schools and recycling awareness campaigns.

(iv) Collection efficiency: one point for each positive answer to the nominal variable: Structured collection system plus the points provided by the respondent on the five-point variables: amount and suitability of equipment for waste collection, efficiency in the collection system and availability of transportation facilities for waste collection.

(v) Legislation: one point for each positive answer to the nominal variable: Does environmental legislation exist? Plus the points provided by the respondent on the five-point variables: adequacy of policy and legal frameworks to manage solid waste, enforcement of the law in practice and clear implementation of the laws of the country by the municipality.

(vi) Local available knowledge as follows: one point for each positive answer to the nominal variable: presence of skilled personnel in the municipality, presence of professionals in the field of waste management working for the municipality and universities offering tertiary education in waste management issues.

The results were initially explored using a Kolmogorov–Smirov test indicating that the data were not normally distributed. Consequently, a non standard parametric test was used in the subsequent statistical analysis (Field, 2009). Spearman's correlation coefficient measures helped to obtain relationships between city factors. The values are at significant levels of $p < 0.01^{**}$ (2-tailed); and $0.05 > p > 0.01^{*}$ (2-tailed). A bi-variate analysis was performed between variables related to technologies, environmental education, socio-cultural, institutional, financial and legal aspects. The information was analyzed using the Statistical Package for Social Sciences (SPSS) Version 17.0.

Principal Component Analysis (PCA) was used with orthogonal rotation (varimax) with the objective to establish the linear components or factors that exist within some of the data. Kaiser–Meyer–Olkin (KMO) statistic was used to assess the adequacy of the PCA to the initial variables measuring the sample adequacy. Bartlett's test of sphericity was applied to examine whether the original data were appropriate for factor analysis (Field, 2009).

5. Results and discussion

5.1. Stakeholders

The stakeholders of waste management systems were identified during the workshops. The main 'recognized'' or formal stakeholders included the local authority, some ministries from central government and private contractors providing services. Participants in the workshops acknowledged the national and the local governments as the most important stakeholders which set up policies and the provision of solid waste management systems respectively. The private contractors are also regarded as important

stakeholders as well as the service users such as: households, civil organizations, commercial and industrial sector. Less mentioned are educational and research institutions, political parties, farmers (including poultries, fisheries), health care centers, media, donor organizations, Chamber of Commerce and Industry, recycling companies, police and religious leaders.

The "unrecognized" or informal stakeholders include waste pickers collecting door to door, at the street or in the disposal site, itinerant waste buyers, junk shop owners and street sweepers.

5.2. Generation and separation

The quantity of solid waste generation is mostly associated with the economic status of a society. Shekdar (2009) suggests that the quantity of solid waste generation is lower in countries with lower GDP. However, this relation cannot be seen from the data presented in Table 1. A possible explanation is that waste generation rates have been collected from information provided in the cities by several sources: municipalities, NGOs, universities, research centers or recorded by the first author and the Gross Domestic Product is an indicator of the economic situation at a national level.

The study investigated the factors affecting waste separation at household level. The most significant correlations found between household separation and city parameters are presented in Table 2. Paper, plastic, glass, food, metal, batteries and electric and electronic waste were the categories used during the survey as a construct called "Household separation".

These findings presented in Table 2 reveal that at the municipal level, the limited knowledge on technologies and good practices for waste management, lack of equipment for the collection of sorted materials and the absence of decision makers interested in environmental issues, hamper the development of waste separation programs. Awareness campaigns influence the behavior of individuals to segregate waste due to their environmental concern and the need to participate in solutions. The livelihoods of many poor people depend on collecting recyclable materials door to door, on the streets or at the disposal site. These waste pickers often pay a fee, therefore; households separate the waste in order to obtain some coins for it. Recycling companies have appeared in the cities due to the increase of prices on these secondary materials. The combination of these two facts seems to have promoted more separation at the household level. Finally, separation is improved when citizens share responsibility with the municipality on the decision making on the waste system of the city.

The PCA performed with the 8 correlated factors allowed three dimensions to be found (Table 3). The PCA revealed that the there are three most important components in relation to the separation of waste. These components are:

Awareness. The efficiency on the separation of waste depends on the awareness of citizens and municipal leaders on the impacts of waste management systems in the city.
Knowledge. Decision makers at the municipality are prone to set up waste separation programs when they are familiar with new and appropriate technologies as well as good practices for the management of waste.
Equipment. The availability of equipment and machinery to manage and recycle waste seem to be key factors that promote separation of waste at the household level.

The factor extraction process shows that awareness explains 44.4% of the total variance of the observed variables, knowledge 17.2% and equipment 11.0%. The three components together account for 72.6% of the initial variance. The KMO measure verified the sampling adequacy for the analysis, KMO = 0.72 which is above the acceptable limit of 0.5 (Field, 2009). Bartlett's test of sphericity χ^2 (55) = 351.268, $p < 0.001$, indicated that correlations between items were sufficiently large for PCA.

5.3. Collection, transfer and transport

The study showed that municipalities collect waste from the commercial areas with frequencies that vary from 14 times a week (e.g. Amasya) to 1 time a week (e.g. Lilongwe). The collection in the inner city also varies from 14 times a week (e.g. Ambon) to 0 (e.g. Asidonhopo). In the studied cities the solid waste generated is

Table 2
Spearman correlation of household separation and city factors.

Separation parameter	City parameter							
	Equipment available	Awareness campaigns	Recycling companies	WP[a] recyclables collection	Interest of leaders in environment	Technology knowledge	Good practices knowledge	Decision making citizen participation
Household (HH) separation	.46**	.55**	.32**	.47**	.40**	.46**	.53**	.50**

[a] Waste pickers.
** $p < 0.01$ (2 tailed).

Table 3
Principle component analysis of household separation and their related city factors after varimax rotation with Kaiser normalization converged in 5 iterations; Only components explaining at least 10% of total variance are included; Loadings over 0.50 are considered relevant; and $n = 50$.

Components	Loadings	Variance explained (%)	Cronbach's alpha
Component 1: awareness		44.4	0.7
Household separation	+0.79		
Awareness programs	+0.64		
Citizens participation in decision making	+0.78		
Leaders interest in environmental issues	+0.59		
Component 2: knowledge		17.2	0.8
Municipality knowledge on solid waste management good practices	+0.69		
Municipality knowledge on technologies for waste management	+0.75		
Component 3: equipment		11.0	0.6
Equipment available to manage waste	+0.57		
Presence of recycling companies in the region	+0.74		

collected at fixed stations or door to door. Few of the cities have transfer stations: Ambon, Jogjakarta, Beijing, Bangkok, Dar es Salam, Emfuleni, Langeberg, Pretoria, Gazipur, and Managua.

The door to door collection is done by a variety of systems. They are: rickshaw (e.g. Kathmandu, Beijing), animal traction (e.g. Nicaragua, Lahore), wheelbarrow (e.g. Hambatota, Lusaka), tractor (e.g. Langeberg, Balangoda), truck (e.g., Kuthaya, Nakuru), compactor (e.g. Banda Aceh, San Jose), tricycle (e.g. Cañete, Gazipur), motorcycle (e.g. Quezon City, Ambon) and hand trolley (e.g. Masaya, Jogjakarta).

Table 4 summarizes the results of a series of correlations between some city factors and household collection, transfer and transport of waste.

Time for collection of waste fitting the service users' needs has a significant relationship to the availability of waste transportation facilities and the quality of the road. When local leaders are interested in solid waste management issues, they allocate adequate funding for equipment and infrastructure. As a result the stakeholders are willing to pay and also to participate in the solutions for an improved service. The providers of waste collection often tend to forget the needs of the service users; therefore the cooperation and coordination between service users and service providers are of great importance.

The analysis of the data suggests that improving the infrastructure, including the roads, increasing the equipment and human resources have a positive impact on the delivery of the service. But these represent an economic burden for the municipalities. Waste collection, transfer and transport are important but expensive municipal services (Faccio et al., 2011). Generally, they constitute 80–95% of the total budget of solid waste management; hence it forms the key component in determining the economics of the whole waste management system (Alagoz and Kocasoy, 2008). The financial support of the Central Government appears to be a solution for the lack of financial resources.

A PCA carried out with 9 correlated factors (Table 5) allowed finding two dimensions; Support and Infrastructure.

Support: Central and local government, service providers and service users' support to the system are key elements for the efficiency of the collection, transfer and transport of solid waste.
Infrastructure. In general, municipalities are responsible for the infrastructure and equipment needed for waste collection, transfer and transport. The improvement of the infrastructure affects positively the efficiency of the system.

The factor extraction process shows that support explains 45.8% of the total variance of the observed variables and infrastructure 15.5%. The two components together account for 61.3% of the initial variance. The KMO measure verified the sampling adequacy for the analysis, KMO = 0.76. Bartlett's test of sphericity $\chi^2(36) = 190.35$, $p < 0.001$, indicated that correlations between items were sufficiently large for PCA.

5.4. Treatment

This research found that 14 of the investigated cities do not have composting practices, while the other 21 compost organic wastes up to some extent, either at the household level, or by the private sector or municipality. In relation to domestic burning of waste, it was found that 22 of the cities report the practice of open burning of waste at the household level.

Table 6 shows the relations between the level of composting, domestic burning and waste treated before disposal with some city parameters.

The results suggest that the level of composting is positively correlated to domestic burning. Improper waste collection systems

Table 4
Spearman correlation of collection, transport and transfer and city factors.

Parameter		Collection, transport and transfer parameter				City parameter					
Group	Item	Collection time fitting users' needs	Amount and suitable equipment	Transportation facilities for sw[a]	Quality of road	Willingness to pay	Willingness to participate in solutions	Priorities for sw[a]	Interest in sw[a]	Coordination & cooperation between SU & SP[b]	Support from the central government
Collection, transport and transfer parameter	Collection time fitting users' needs	1.00									
	Amount and suitability of equipment	.29*	1.00								
	Transportation facilities for sw[a]	.38**	.67**	1.00							
	Quality of road	.46**	.30*	.47**	1.00						
City parameter	Willingness to pay	.30*	.54**	.59**	.48**	1.00					
	Willingness to participate in solutions	.30*	.49**	.37**	.01	.33*	1.00				
	Priorities for solid waste	.28	.30*	.17	.18	.04	.26	1.00			
	Interest in solid waste	.48**	.70**	.48**	.36*	.42**	.52**	.39**	1.00		
	Coordination and cooperation between SU & SP[b]	.39**	.55**	.29*	.43**	.46**	.47**	.18	.70**	1.00	
	Support from central government	.39**	.64**	.40**	.22	.46**	.39**	.15	.74**	.69**	1.00

[a] Solid waste.
[b] Service users and service provider.
** $p < 0.01$ (2 tailed).
* $0.05 > p > 0.01$ (2 tailed).

Table 5
Principle component analysis of collection, transfer and transport factors and their related city factors after varimax rotation with Kaiser normalization converged in 5 iterations; Only components explaining at least 10% of total variance are included; Loadings over 0.50 are considered relevant; and $n = 50$.

Components	Loadings	Variance explained (%)	Cronbach's alpha
Component 1: support		45.8	0.9
Support from central government	+0.87		
Interest of municipal leaders in solid waste management issues	+0.82		
Coordination & cooperation between service users and service providers	+0.81		
Stakeholders willing to participate in the solutions of improved service	+0.66		
Stakeholders willing to pay for waste services	+0.57		
Component 2: infrastructure		15.5	0.6
Quality of road	+0.86		
Amount and suitable equipment	+0.83		
Collection time fitting users' needs	+0.72		
Priorities of decision makers in solid waste issues	+0.63		

Table 6
Spearman correlation of waste treatment and city factors.

Parameter		Treatment parameter			City parameter		
Group	Item	Level of composting	Level of domestic burning	Waste treated before disposal	Suitability of infrastructure	Leaders interest in environment	Efficiency of municipal management
Treatment parameter	Level of composting	1.00					
	Level of domestic burning	.39**	1.00				
	Waste treated before disposal	.24	−.11	1.00			
City parameter	Suitability of infrastructure	.33*	−.32*	.29*	1.00		
	Leaders interest in environment	.20	−.28	.33*	.52**	1.00	
	Efficiency of municipal management	.14	−.40**	.29*	.55**	.52**	1.00
	Local knowledge	.35**	0–.06	−.01	−.10	−.09	−.16

** $p < 0.01$ (2 tailed).
* $0.05 > p > 0.01$ (2 tailed).

due among others to lack of infrastructure or municipal inefficiencies, promote people finding solutions for their waste such as domestic burning (combustible materials) and composting the putrescible fraction.

In relation to municipal composting Shekdar (2009) argues that many composting facilities have been shut down, among others, due to inadequate monitoring of the quality of the compost being produced and incompatibility of plant design with the characteristics of the solid waste. Both factors are related to local available knowledge and appropriate infrastructure.

5.5. Final disposal

Most of the disposal sites in the studied cities are open dumps without leachate treatment, protection at the bottom by a geomembrane or clay-lined layer, gases treatment nor other infrastructures needed. They receive a diversity of waste as shown in Table 1. The distances to the official most important disposal sites vary from 3 km in Hambantota to 50 km in Beijing from the city centers. Besides the official disposal sites, the cities suffer from the illegal disposal of waste in rivers, lakes, oceans, drainage channels, empty lots and roadsides.

This study investigated the practice of covering the waste at the disposal site. Table 7 presents the outcomes which suggest that waste is covered at the disposal site if the municipal leaders or decision makers are interested in environmental and solid waste management issues. The provision of equipment and infrastructure are essential for an efficient system. The existence of a legal framework with effective enforcement of the rules facilitates the planning and operation of the system. This result is also in agreement with some of the findings of Shekdar (2009) among others.

5.6. Recycling

Recyclable materials included in this study were: plastic, paper, metal, glass, organic, battery, electric and electronic. Table 8 reports the results of the correlation analysis between recyclables collection and some city factors.

The findings suggest that when citizens receive information about the benefits of recycling, how to sort the waste and they participate in the designing of the programs, they are more likely to participate in recycling campaigns. It was also found that when municipal leaders are interested and give priority to solid waste issues, they support strategies which include more efficient collec-

Table 7
Spearman correlation of disposal and city factors.

Disposal parameter	City parameter				
	Leaders interest in environment	Amount and suitability equipment	Suitable infrastructure	Leaders interest in solid waste	Legal framework
Waste covered at disposal site	.67**	.63**	.56**	.67**	.52**

** $p < 0.01$ (2 tailed).

Table 8
Spearman correlation matrix of recyclables collection and city factors.

Recycling parameter	City parameter						
	Legal framework	Awareness campaigns	Suitable infrastructure	Efficient collection	Low cost technologies available	Decision making citizen participation	Interest in solid waste
Recyclables collection	.46**	.55**	.32**	.47**	.40**	.46**	.53**

*0.05 > p > 0.01 (2 tailed).
** p < 0.01 (2 tailed).

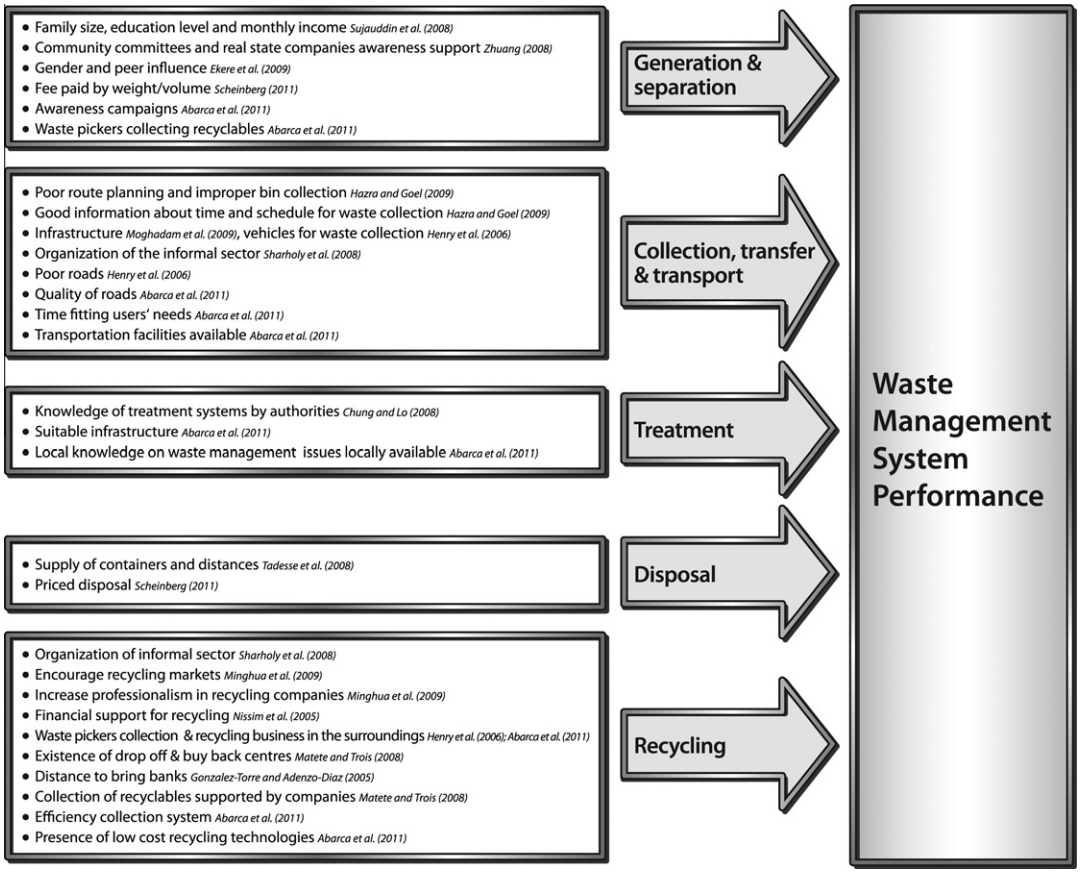

Fig. 2. Factors that influence the elements of waste management systems.

tion systems, better infrastructure and low cost recycling technologies. The success of recycling not only depends on participation levels but on the efficiency of the equipment and infrastructure. These results are in agreement with the findings of Manaf et al. (2009) who report that the irregular collection services, inadequate equipment used for waste collection, inadequate legal provisions are key factors that are challenging the waste recycling scenario in Malaysia today.

5.7. Summary of factors affecting performance of solid waste management systems

Figs. 2 and 3 summarize the factors reported in literature and the findings of the present study affecting the performance of solid waste management systems. Some factors influence individual elements (Fig. 2) while others affect the whole waste management system (Fig. 3). Some factors have been mentioned in literature by several scholars and by the first author of this article in different reports, but only the author(s) of one article or report is mentioned for simplicity of the figures.

6. Conclusions

The studied cities are a mixture of cultures and so is the variety of solid waste management systems. The outcome of this analytical research provides a comprehensive analysis on stakeholders and some key factors that affect those systems. The key findings are outlined below:

1. Waste management involves a large number of different stakeholders, with different fields of interest. They all play a role in shaping the system of a city, but often it is seen only as a responsibility of the local authorities. In the best of the cases, the citizens are considered co-responsible together with the municipality. Detailed understandings on who the stakeholders are and the responsibilities they have in the structure are important steps in order to establish an efficient and effective system. Communication transfer between the different stakeholders is of high importance in order to get a well functioning waste management system in the cities in developing countries.

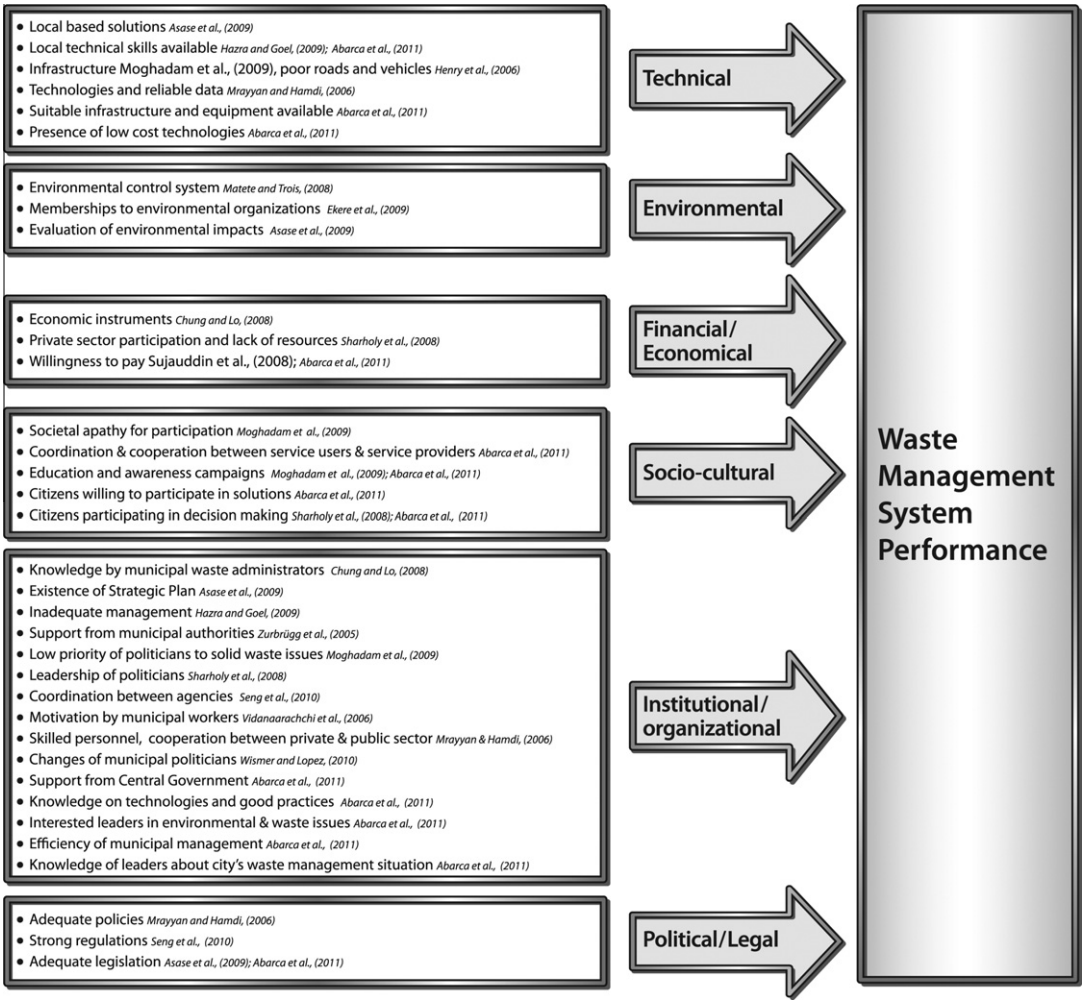

Fig. 3. Factors that influence the aspects of waste management systems.

2. Solid waste management is a multi-dimensional issue. Municipalities in general seek for equipment as a path to find solutions to the diversity of problems they face. This study shows that an effective system is not only based in technological solutions but also environmental, socio cultural, legal, institutional and economic linkages that should be present to enable the overall system to function.
3. Solid waste services have a cost as any other services provided but in general the expenditures are not recovered. Resources are required with the objective of having skilled personnel, appropriate equipment, right infrastructure, proper maintenance and operation. The financial support of the central government, the interest of the municipal leaders in waste management issues, the participation of the service users and the proper administration of the funds are essential for a modernized sustainable system.
4. Fundamental is to produce reliable data and to create proper information channels within and between municipalities. Decision makers, responsible for planning and policy making, need to be well informed about the situation of the cities in order to make positive changes, developing integrated waste management strategies adapted to the needs of the citizens considering their ability to pay for the services.
5. Universities, research centers and centers of excellence have a very important role in preparing professionals and technicians in environmental fields, including waste management. Some developing countries have already seen the positive effects of investing in education and research by having cleaner cities, citizens assuming their responsibilities and higher status of solid waste workers.
6. The questionnaire prepared to structure and collect information enabled to develop a snap shot or baseline information on what is happening in the city (Appendix A). It is relatively easy to use, applicable for urban and rural settings and can be applied by people with different education levels.
7. The information provided about the factors influencing solid waste management systems is very useful for any individual or organization interested in planning, changing or implementing a waste management system in a city.

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Appendix A. Characterization of waste management practices

Description	Answers
Date	
Country of investigation	
Perinatal mortality	
Adult mortality	
Life expectancy at birth	
Healthy life expectancy at birth	
Gross Domestic Product/capita	
Ecological footprint/capita	
CO_2-emission/capita	
Persons/km^2	
% urban population	
Province of investigation	
City, town, village of investigation	
The total number of persons inhabiting the city	
Full name of person giving the information or number of participants	
Solid waste management stakeholders present in the city	
Type of waste brought to the community official disposal site	1 = Household; 2 = institutional; 3 = construction, 4 = health care; 5 = agriculture; 6 = industry; 7 = commercial
Community urban or rural	
Waste generation index (kg/capita/day) city/country	
Budget of municipality for waste management services per year	
Extend of waste separation at the house level	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Extend of waste separation at the business level	1 = None; 2 = some; 3 = half; 4=most; 5 = all
Extend of plastic waste separation at the municipality level	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Extend of paper waste separation at the municipality level	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Extend of metal waste separation at the municipality level	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Extend of glass waste separation at the municipality level	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Extend of organic waste separation at the municipality level	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Extend of battery separation at the municipality level	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Extend of medical waste separation at the healthcare centers	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Extend of electric and electronic waste separation at the municipality level	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Extend of waste dispersed in the city	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
The collection of waste is done by: (you can write more than one)	1 = Municipality; 2 = private sector; 3 = waste pickers; 4 = children; 5 = public private partnership; 6 = transfer point (station); 7 = other
Frequency of waste collection at commercial sites (times/ week)	
Frequency of waste collection at inner city (times/ week)	
Frequency of waste collection at rural areas (times/ week)	
Type of vehicle(s) used to collect the waste (you can write more than one)	1 = Rickshaw; 2 = wheelbarrow; 3 = truck; 4 = tractor; 5 = compactor; 6 = animal; 7 = tricycle; 8 = motorcycle;

(***continued on next page***)

Appendix A (***continued***)

Description	Answers
	9 = handtrolley; 10 = other
Price or fee for the collection service (write it in your own currency) (year)	
Collection time fitting users' needs	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Waste transfer station(s) in the city	1 = Yes; 2 = no
Streets used as transfer stations	1 = Yes; 2 = no
Schedule for waste collection at transfer station(s) accomplished	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Hazardous waste placed on the streets	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = Always
Waste littering the road while transported	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Waste treated before disposal	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Hazardous waste being treated	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Presence of illegal dumping sites in the city	1 = Yes; 2 = no
Presence of official disposal site	1 = Yes; 2 = no
Presence of well engineered disposal site	1 = Yes; 2 = no
Performance of landfill	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent 6 = NA
Distance to the disposal site (km)	
Waste at the illegal disposal site(s) covered	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Waste covered at formal disposal site	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Control of healthcare waste treatment and disposal	1 = Never; 2 = sometimes; 3 = often; 4 = very Often; 5 = always
Level of composting done by households, private sector or municipality	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Compost produced by municipality	1 = Yes; 2 = no
Quality of compost controlled	1 = Yes; 2 = no
Market for compost	1 = Yes; 2 = no
Practice of biogas production with HH waste	1 = Yes; 2 = no
Level of domestic burning of waste at household level	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Practice to use reusable shopping bags	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Restaurant waste used to feed animals	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Paper reused within the municipality	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Glass bottles reused within the municipality	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Metal scrap used in the municipality	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Recyclables goods collected by waste pickers	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Waste pickers pay a fee for the recyclables they collect	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Waste pickers criminalized	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Recyclables goods buying companies in the surroundings of the city	1 = None; 2 = few; 3 = some; 4 = many; 5 = very many
Recycling companies in the surroundings of the city	1 = None; 2 = few; 3 = some; 4 = many; 5 = very many
Presence of waste reduction strategies in the city	1 = Yes; 2 = no
NGOs responsible for waste reduction campaigns	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Reduction campaigns performed at schools	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Recycling awareness campaigns supported by municipality	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Municipality's authorities knowledge on the city waste situation	1 = None; 2 = very little; 3 = little; 4 = sufficient; 5 = extensive
Municipality has a swm plan	1 = Yes; 2 = no
Municipality has standards for the swm system	1 = Yes; 2 = no
swm standards monitored	1 = Yes; 2 = no 3 = NA
Structured collection system for sw available in the community	1 = Yes; 2 = no
Efficiency of the sw collection system (in terms of what is offered by the provider and what the users receive)	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent
Available transportation facilities for sw collection	1 = None; 2 = very little; 3 = little; 4 = sufficient; 5 = extensive
Amount of equipment available to manage sw	1 = None; 2 = very little; 3 = little; 4 = sufficient; 5 = extensive
Suitability of the infrastructure to manage sw	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent
Quality of the road(s) for sw collection	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent
Waste considered by the municipality authorities as a resource	1 = Yes; 2 = no
Knowledge of municipal workers on technologies for swm	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = Excellent

Appendix A (***continued***)

Description	Answers
Knowledge of municipal workers on good practices for swm	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent
Citizens participating in the decision making processes for swm	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Municipal authorities perceived high cost for alternative technologies for swm	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Local available low cost technologies for swm	1 = None; 2 = very few; 3 = few; 4 = sufficient; 5 = extensive
Local available professionals in the field of swm working for the municipality	1 = None; 2 = very few; 3 = few; 4 = sufficient; 5 = extensive
Municipality has skilled personnel	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Presence of health campaigns in the community	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Presence of environmental awareness campaigns in the city	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Solid waste service provided for free	1 = Yes; 2 = no
Cost recovery for sw services	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Community willing to pay for waste collection	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Options for implementation of fees according to income of waste generators	1 = Yes; 2 = no
Available costing system in the municipality	1 = Yes; 2 = no
Limited financial resources at the municipal departments	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Dependency on finances coming from development cooperation	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
National governmental financial support to the municipality	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
National governmental supporting other issues different from finances	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Presence of economic instruments (fees, subsidies, taxes)	
Private sector providing waste collection	1 = Yes; 2 = no
Private sector participating in swm services different than collection	1 = Yes; 2 = no
Public awareness campaigns available for wm in the community	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = Always
Stakeholders willing to participate in the wm solutions	1 = none; 2 = some; 3 = half; 4 = most; 5 = all
Collaboration among stakeholders	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent
Presence in the community of active public platforms	1 = None; 2 = few; 3 = some; 4 = many; 5 = very many
Municipal leaders interest in environmental issues	1 = None; 2 = few; 3 = some; 4 = many; 5 = very many
Inconsistencies between different governmental agencies for wm	1 = None; 2 = few; 3 = some; 4 = many; 5 = very many
Your perception of the organization of the municipality	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent
Municipal workers willingness to change their ways of working	1 = None; 2 = few; 3 = some; 4 = many; 5 = very many
Municipal authorities have priorities for other urgent topics than swm	1 = Never; 2 = sometimes; 3 = often; 4 = very often; 5 = always
Level of interest of political authorities in wm issues	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent
Level of motivation of the municipal workers	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent
Level of corruption within municipality	1 = None; 2 = low; 3 = average; 4 = high; 5 = very high
Level of coordination and cooperation between service users and service providers	1 = Very bad; 2 = dad; 3 = good; 4 = very good; 5 = excellent
Extend to which goals and objectives of service users and service providers are shared	1 = None; 2 = some; 3 = half; 4 = most; 5 = all
Adequacy of policy and legal frameworks to manage sw	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent
Environmental legislation in place	1 = Yes; 2 = no
Practice of law enforcement	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent
Clear implementation of the countries' laws by the municipality	1 = Very bad; 2 = bad; 3 = good; 4 = very good; 5 = excellent

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