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Sample of Batman in determination of urban solid waste management and recycling potential

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The collection, transport, treatment, and disposal of solid wastes, particularly wastes generated in medium and large urban centres, have become a relatively difficult problem to solve for those responsible for their management. However, recycling-related activities bring waste reduction, prevention of waste of raw materials and less environmental damage as well as providing an economic benefit to the countries. In this paper, a case study of a developing country has been examined dealing with serious pollution problems due to the ineffective management of the large solid waste generated in the city of Batman in Turkey. The aim of this paper is to estimate the quantity of waste produced that requires collection and the different waste constituents, to analyze the current practices of SWM, to propose an environmentally sound and economically feasible integrated management system for dealing with solid waste. Results showed that the average generation rate of MSW was 0.75 kg/capita/day in Batman and also, it has been anticipated that the wastes could be disposed by using modern methods instead of irregular storage.

Key words: Batman City, disposal of solid wastes, recycles solid waste management.

INTRODUCTION

Solid waste management (SWM) is one of the priority issues concerning protection of the environment and conservation of natural resources. Actually, there is an increasing attention by managers and planners to follow a sustainable approach to waste management and to integrate strategies that will produce the best practicable option. That is a quite hard task, as it is necessary to properly take into account economic, technical, and normative aspects, paying particular attention to environmental issues (Costia et al., 2004).

In non-industrialized nations, on the other hand, the public's general lack of environmental knowledge and awareness, and the constant enlargement of areas of landfill disposal sites constitute major issues (Koushki and Alhumoud, 2002).

Especially rapidly growing populations, rapid economic growth and rise in community living standards have accelerated the generation rate of municipal solid waste (MSW) causing its management to be a major worldwide challenge (Seo et al., 2004). Particularly in urban cities of developing countries, MSW management is a highly neglected area (Zhen-shan et al., 2009; Batool and Ch, 2009; Chung and Carlos, 2008; Imam et al., 2008; Berkun et al., 2005; Metin et al., 2003; Ahmeda and Alib, 2004).

The awareness that improper handling of MSW leads to contamination of water, soil and atmosphere and is a major impact on public health has caused developing nations to address this issue with increasing urgency (Batool et al., 2009; Sharholy et al., 2008).

Some of the authors of the present paper have recently presented a decision model (Chang et al., 1998), based on the same approach as, but within a more general modeling framework, both as regards the system representation and the decision variables considered (Fiorucci et al., 2003).

However, an approach merely based on economic considerations cannot be considered as completely satisfactory in connection with waste management

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Table 1. Studied waste components and ratios of Batman City.

Component	Monthly (tons)	
	Summer	Winter
Cardboard	30	6
Plastic bags	6	2 - 3
Plastic bottle, detergent boxes	8	4
Aluminum	0.3	0.3
Metal boxes	0.3	0.3
Iron	0.8	1
Tin	9	18

problems. In fact, a wide set of possible developments can be pursued. Above all, modeling the environmental impact of SWM requires the modeling and analysis of a quite heterogeneous set of subsystems, which are affected by the decisions concerning SWM. For instance, among such subsystems, one can mention the atmospheric pollution model, the city traffic system, the sanitary landfill, etc. In this connection, some suggestions may come from recent works. For instance, Tsiliyannis (1999) discussed the main environmental problems related to MSW management, and in particular those concerning pollutant releases. Chang and Wang (1997) proposed a fuzzy goal programming approach for optimal planning of MSW systems, in which they consider four objectives: economic costs, noise control, air pollution control, and traffic congestion limitations. Another possible approach was based on life cycle assessment (Finnveden, 1999; Barton et al., 2000). Specifically, Finnveden (1999) discussed some methodological issues that arise in connection with such an approach. Moreover, the waste reduction problem could be studied at a more general level, taking into account issues concerning the design of production processes (Young et al., 1996).

Actually, planning a MSW management system is a very complex task, because it is necessary to simultaneously consider conflicting objectives; in addition, such problems are generally characterized by an intrinsic uncertainty as regards the estimates of costs and environmental impacts. Such reasons have led to several authors (Chang and Wang, 1997; Hokkanen and Salminem, 1997; Karagiannidis and Moussiopoulus, 1997) introduce and apply multi-criteria decision techniques.

As regards the detailed treatment of the dynamics of pollution processes deriving from MSW management, many authors have developed models aiming at representing chemical processes and reactions that take place in the various plants used in a MSW management system. Specifically, a crucial issue is that concerning the modeling of the formation of pollutants deriving from combustion or from specific processes (Chang and Chang, 1998). A recent work (Chang et al., 1998) has paid a great attention to the impact of solid waste presorting on incineration facilities, through the evaluation of the comparative effects of burning MSW in the same incinerator.

Specific issues comparatively analyzed are heat balance, ash properties, and the quality of flue gas in the incineration process. Morf et al. (2000) have paid particular attention to material balances and to the determination of coefficients expressing the input/output fraction. Moreover, they have used statistical techniques to analyze the uncertainty arising from variations in input waste variations and process conditions. Björklund et al. (1999) have used a substance-flow simulation model, namely the organic waste research model (ORWARE), to evaluate economic aspects and environmental impacts, and comparing three scenarios: incineration with heat recovery, composting and anaerobic digestion.

In this study, solid waste disposal methods were examined in a way to give the least harm to the environment. These methods were evaluated for solid wastes of the province of Batman.

MATERIALS AND METHODS

Solid waste is all kinds of materials that are generated within production and consumption process of humans and thus generated as a result of industry, commerce, social service and similar activities, which become useless and do not include liquid that would become fluent. Solid wastes are examined in two groups: according to their origin and composition. The first group is domestic wastes, garden wastes, school and hospital wastes, construction and debris wastes, municipal wastes, refinery facility wastes, industrial wastes, agricultural wastes, radioactive wastes and specific wastes. Solid wastes are classified as organic and inorganic according to their composition. Composition of solid wastes is continuously changing. Changing compositions and characteristics can be mentioned even in the same settlement. Solid waste composition of Batman Province is given in Table 1.

These components and others vary according to countries, seasons, and cities. In Table 2 amounts of solid waste collected from Batman are given. Solid waste management is a process that produces appropriate solutions by using principles of several disciplines (public health, economy, and engineering) in phases that begin with the generation of wastes to their final disposal. In solid waste management, compositions and ratios have to be searched and controlled so as to cover all seasons and, if possible, months. In the case where solid waste components are known, wastes can

Table 2. Amount of waste collected from Batman City.

Description	Unit	Quantity (Winter)	Quantity (Summer)
Population	Person	303.712	303,712
The total daily waste separately collected and weighed by the municipality (except for ash)	Ton/day (average of 7 days)	238.6	217.4
Waste collection rate	%	99	99
Wastegenerationperperson	Kg/person/day	0.79	0.72

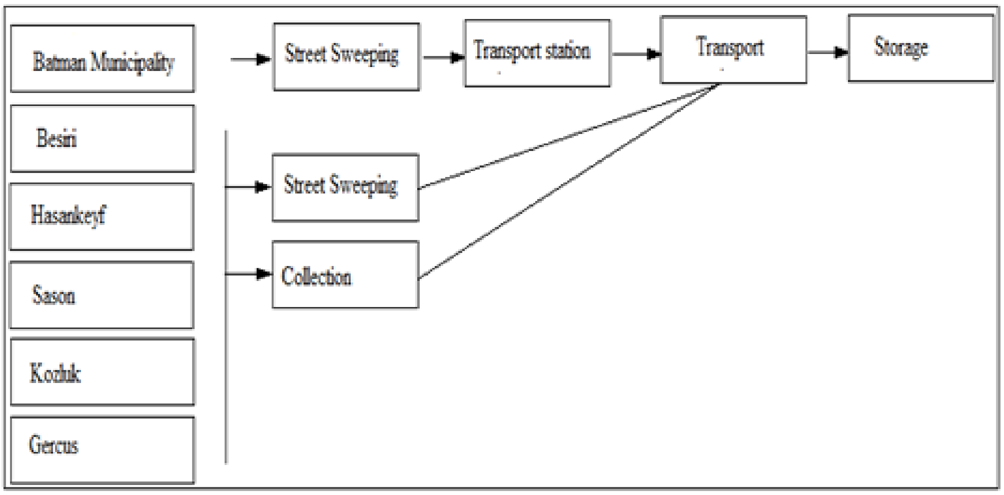

Figure 1. The current solid waste management plan of Batman.

be utilized and disposed properly in the most appropriate manner for the environment.

Solid waste components can be examined in 3 groups:

a. Flammables: organic materials, food wastes, paper, cardboard, plastic, textile, wood etc.
b. Recyclables: plastic, glass, metal, paper etc.
c. Compostables: food wastes, paper, cardboard, plant wastes, ash, soil etc.

Solid waste management in municipalities are conducted under the name of solid waste management cleaning services and usually by cleaning services units. Cleaning services is a process that includes regular collection of refuses, garbage or waste materials that constitute the object of these services, their evaluation and disposal of those that are not evaluated with appropriate tools. In Figure 1, the schema for Batman Province that present solid waste management is provided.

An integrated system is needed for an efficient solid waste management. Solid waste management must be planned so as to include all materials that constitute the composition of the solid waste generated in a settlement as well as their generation sources. For this effect especially the determination of present situation (population, amount and characteristics of solid waste and type of removal) and projections for the future (possible changes and developments in population, amount and characteristics of solid waste) should be performed. Collection and accumulation alternatives must be systematically determined and tools with proper size and features must be chosen. Depending on the distance between solid waste generation and disposal facilities, the necessity for transfer stations must be searched and properly projected.

After the solid wastes are collected, they have to be passed through separation, processing and conversion procedures followed by final disposal. In addition, solid waste system must be able to create economic value (recyclable materials, compost, biogas etc.); for this effect, regional plans also have to be made in addition to city level plans. Furthermore, solid waste management system must be flexible enough to be able to adapt itself at a certain rate to the possible changes in solid waste management system, environmental, spatial and waste features depending on time (Metin, 1996). Recycling means using wastes as a raw material to transform them into a new material such as bottle, box, plastic, paper or fertilizer. The most important step of recycling process is represented by separation at source and separately collection. When these wastes which are recyclable are mixed with regular wastes, secondary materials produced from these materials have much less quality.

According to researches, the energy consumed to regain metals is much less than the energy needed to extract them from mines. So much so that the energy needed to make 1 ton of aluminium from recycled metal is 4% of the energy needed to produce aluminium from the ore. Similarly the energy needed for recycling copper compositions is 13% of the energy needed to extract copper from ores; this ratio is 19% for iron-steel. Likewise, 17 trees and 4100 kWh energy is saved by recycling 1 ton of used paper (www.atikyonetimi.cevreorman.gov.tr). Five basic steps of recyclingare: separating at source, separate collection of evaluable wastes, classification, evaluation and gaining the new product for the economy. Different technologies have been developed to

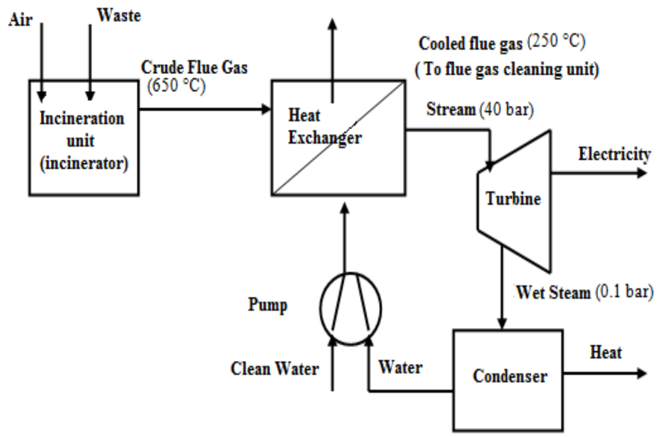

Figure 2. Schematic diyagram of electricity generation.

ensure that solid wastes are terminated without polluting the environment.

Among these methods, the most widely used ones are temporary storage, composting, incinerating, pyrolysis, gasification and vitrification. Composting is biological dissolution of organic materials under controlled conditions. After a completed composting process, the compost product can be used as a fertilizer. By using composting facilities, the amount of wastes that are sent to storage can be reduced almost by 50%. Incineration is thermal oxidation of organic materials that are found in the structure of solid wastes. Incineration is a method which decreases garbage by 70 to 80%. As a result of this method, in addition to taking special measures against air pollution so as not to give any damage to the environment, additional precautions have to be applied to avoid the negative effects of toxic materials that could be included in the ashes being removed. The most scoria is generated by incinerating solid waste.

This scoria is wetted by collecting in a watery scoria tank. Almost 15 to 30% of the raw garbage is turned into scoria. Another product generated by incineration is volatile ash. Incinerating gas consists of 5 to 10 g/Nm^3 dust. Thus, 25 to 50 kg of volatile ash is generated from one ton of raw garbage. Volatile ashes are removed through a closed system along with the scoria. Incineration is mostly applied under the following conditions:

i) In metropolitan areas with a shortage of landfill area due to high levels of volume and weight downsizing ratios.
ii) In cases where final product has to be stabilized, such as hospital garbage.
iii) When energy is to be produced from solid wastes with high thermal value (Yaman, 2006).

Pyrolysis is thermal disintegration of solid wastes as a result of heating them (400 to 800°C) in a reactor with no or little oxygen. Contrary to incineration and gasification processes which show exothermic reactions, pyrolysis is an endothermic process (Akpinar, 2006). The major purpose of gasification process is to create a flammable gas rich in some replete hydrocarbons such as hydrogen (H_2) and methane (CH_4). Vitrification is a waste refining process which transforms waste materials into glass or glass-like stable, usable and safe products under high temperatures (1200 to 1600°C) (Ergun, 2002). There are several methods of obtaining energy from solid wastes. For example, a gas mixture originates as a result of fermentation of animal wastes in oxygen less environment. Obtained biogas provides benefits both as an essential energy input both for electricity and heat generation. Schematic diagram of electricity generation is shown in Figure 2 (Bischoff and Schmidt, 1994).

RESULTS AND DISCUSSION

The calculations have been made for a sample solid waste incineration facility for the province of Batman at the moment, solid wastes generated in Batman are removed by means of irregular storage in an area. According to the information obtained from Batman Municipality, it will be appropriate to take the amount of solid waste produced in Batman Province as 0.75 kg/person-day in winter. Total amount generated in wintercan be calculated as 303712 persons × 0.79kg/person-day × 180 days/year × 1 ton/1000 kg = 43187.84 tons/year. In summer, this can be calculated as 303712 persons × 0.72 kg/person-day × 185 days/year × 1ton/1000kg = 40454.43 tons/year. Total amount generated in a year can be calculated as a 83642,27 tons/year.

When the calorific value of the input wastes is accepted as 8000 kJ/kg (raw waste), the energy obtained is 1.67 kWh/(kg input waste).

83141.16 tons waste/year × 8000 kjs/kg waste × 1000 kg/ton × 1 kcal/4.18 kJ = 159.1 × 109 kcal/year = 18 162 100 kcal/ h ≈ 19 000 000 kcal/h heat can be obtained.

83141.16 ton waste/year × 1.67 kWh/kg waste × 1000 kg/ton = 138.84 × 10^6 kWh/year energy will be obtained.

If $\eta_{transform}$ = % 40 is taken 55.53 × 10^6 kWh/year electrical energy can be obtained. If this value is divided by the population of Batman; it is estimated as 66.91 kWh/ capita/year. When this result is compared with study done by Magrinho et al. (2006) where this value was 57.2 kWh/ capita/year, a better result is observed.

When we consider that the heating demand of a 100 m^2 residence is 10 000 kcal/h, the heating demand of 1900 residences can be met (19 000 000 kcal/h) / (10 000 kcal/h). When we consider that an average residence needs 3600 kWh electricity energy annually, the need for electrical power of 15 427 residences will be met (55.53 × 10^6 kWh/year) / (3600 kWh/year). In Table 3, estimated calculations are made for a solid waste incineration facility with 83141.16 tons annual waste capacity (Kayalak, 2007).

The information given above for consumption or waste generation per unit is average values. Annual payment coefficient is found by envisaging that 15 years of loan will be used with 10% annual interest. Total cost is multiplied with loan payment coefficient so as to calculate the total annual fixed expenses. The balance is found by subtracting total expenses from total revenue. Unit cost of one ton of waste is calculated by dividing the unit cost by total amount of wastes.

Unit cost of one ton of waste is found as 142 Euros.

Table 3. Investment and calculation example for Batman Province solid waste incinerating facility.

Capacity		**83642.27 t/year**		
Fixed expenses: Investment expenses	**Loan period**	**Interest rate (%)**	**Total cost (Euro)**	**Annual cost (Euro/year)**
Mechanical equipment	15	8	60000000	5000000
Electrotechnic equipment	15	8	16500000	1375000
Construction	15	8	20000000	1660000
Fees	15	8	6500000	545000
Coefficient of the annual loan payment		0.12		
Total			103000000	12360000
O&M costs				Annual expense (Euro)
Care and repair				
Mechanical equipment	4% of the investment for mechanical equipment		2400000	
Electrotechnic equipment	1.5% of for electric equipment investment		247500	
Construction	1% of the investment made for construction		200000	
Taxes	1% of the total investment		1030000	
Insurance expenses	0.3% of the total investment cost except for payment		289500	
	Personnel	Payment (Euro/month)		
Personnel expenses	50	1000	50000	
Management	5% of personal expenses		2500	
Total				4219500
Raw material costs				
Replacement parts	5% of total care/repair expenses		142375	
	Unit	**Unit/t waste**	**Unit cost (Euro/unit)**	
Fuel	kg	4.6	3.5	1346636
Usage water	m^3	2	1	167285
Drinking water	m^3	0.05	1,5	6273
Lime	kg	4.6	0.1	38475
Ammonia solution	kg	4	0.3	100370
Disposal of slag	t	0.291	25	608495
Disposal of plaster	kg	9.3	0.02	15558
Disposal of filter waste	kg	20	1.2	2007408
Disposal of salt and mud	kg	4.6	1	384755
Total				4625255
Total expenses				**21204755**
Incomes				
	Unit	**Unit/t waste**	**Unit cost (Euro/unit)**	
Selling of H_2SO_4 (t)	t	0.016	2000	2676544
Selling of scarp metal	t	0.033	100	276019
Selling of slag	t	0	2	0
Selling of heat	kWh	450	0.20	7527780
Selling of electric	kWh	280	0.03	702593
Total incomes				11182936
Balance sheet (Expenses-Incomes)				10021819
Unit cost (Euro/t raw waste)	120			

Two hundred Euros can be determined as disposal price for each ton of waste that will be sent to the facility. Thus, a huge relief will be made for operating the facility.

Conclusion

The amount of solid waste collected in Batman was 83,141 ton in 2003, and MSW is mostly composed of domestic residues, and its composition varies by season. Solid waste generated generally consists of a high organic fraction because of high consumption of vegetables and fruits. In rural areas, the ash content is higher due to the use of stoves for heating purposes in the winter. In Batman as in many cities of Turkey, there is lack of organization and planning in MSW management due to insufficient information about regulations and due to financial restrictions. In the short term, the best policy might be to leave disposal methods without any controls, and use the resources available to upgrade them with environmental protection systems. In the long term, the construction of new sanitary landfill areas, composting, and incineration facilities could be planned. Public participation and awareness are also important issues in achieving the goals of the suggested management system, but it is difficult and takes a long time to make people aware of the importance and of the principles of the proposed management system and to affect their participation.

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