Artvin Çoruh Üniversitesi
Doğal Afetler Uygulama ve Araştırma Merkezi
Doğal Afetler ve Çevre Dergisi

Artvin Çoruh University
Natural Hazards Application and Research Center
Journal of Natural Hazards and Environment

Araştırma Makalesi / Research Article, Doğ Afet Çev Derg, 2020; 6(1): 90-97, DOI: 10.21324/dacd.467179

Materials Flow Analysis as a Tool to Improve Solid Waste Management: A Case of Ankara

Nesli Aydın[1,*]

[1]*Namık Kemal University, Faculty of Engineering, Department of Environmental Engineering, Tekirdağ.*

Abstract

The progress of recent civilisation and the associated growth in population worldwide has contributed considerably to the increase in the quantity of waste produced. The ever-increasing consumption of resources has resulted in high amounts of solid waste from domestic activities, which can pose significant threats to the environment and human health. Waste management and recycling activities have a complex and multifaceted mechanism that requires comprehensive and integrated approaches. In this study, the current status of municipal solid waste management in Ankara was identified and waste streams were investigated by using Materials Flow Analysis (Stan 2 software). It was aimed to analyse material flows by visualising the waste management system of Ankara. This study resulted that approximately 1.6 million tonnes of solid waste is collected per year (4500 tonnes per day) in the province. Almost 470 thousand tonnes of it is being used for methane production and more than 400 thousand tonnes of compost is being produced each year. The result of the model also points out that 286 thousand tonnes get accumulated in landfills each year. This reveals the possible requirement for a capacity investment of Mamak Landfill Area, which is already on the agenda of city authorities.

Keywords
Waste Management, Quantity of Waste, Waste Streams, Solid Waste, Materials Flow Analysis

Katı Atık Yönetiminin Geliştirilmesinde Malzeme Akış Analizi: Ankara Örneği

Özet

Sürekli gelişim ve buna bağlı olarak dünya çapında nüfusla ilişkili büyüme, üretilen atık miktarındaki artışa önemli ölçüde katkıda bulunmuştur. Giderek fazlalaşan kaynak tüketimi, üretilen evsel katı atık miktarının artmasına neden olmuş, bu da çevre ve insan sağlığı için önemli bir tehdit oluşturmaya başlamıştır. Atık yönetimi ve geri dönüşüm faaliyetleri, kapsamlı ve entegre yaklaşımlar gerektiren karmaşık ve çok yönlü bir mekanizmaya sahiptir. Bu çalışmada, Ankara ilindeki evsel katı atık yönetiminin mevcut durumu belirlenip, katı atık akımları, Malzeme Akış Analizi (Stan 2 yazılımı) kullanılarak araştırılmıştır. Bu çalışmanın amacı, Ankara ilinin atık yönetiminin görsel olarak ortaya çıkarılıp atık akımlarının analiz edilmesidir. Bu çalışma göstermiştir ki, Ankara'da her yıl yaklaşık 1,6 milyon ton katı atık (günde 4500 ton) toplanmaktadır. Toplanan bu atıkların yılda yaklaşık 470 bin tonluk kısmı metan üretimi için, 400 bin tondan fazlası ise kompost üretimi için kullanılmaktadır. Ayrıca, model sonucuna göre düzenli depolama alanlarında her yıl 286 bin ton atık biriktiği tespit edilmiştir. Bu durum, şehir yetkililerinin de gündeminde olan Mamak Atık Depolama Sahası için kapasite arttırımı ihtiyacına işaret etmektedir.

Anahtar Sözcükler
Atık Yönetimi, Atık Miktarı, Atık Akımları, Katı Atıklar, Malzeme Akış Analizi

1. Introduction

Rapid economic growth, rising population and change in living standards contribute to increasing the production of municipal solid waste. In today's world, waste management has gained a considerable importance in order to prevent negative effects to the environment and humans. In Turkey, especially in large provinces, the concept of waste has become a resource that needs to be evaluated and recovered rather than being a problem to be eliminated. In this regard, the development of waste management plans and strategies has begun to form the agenda of municipalities, provincial directorates and development agencies.

Current global municipal waste generation is approximately 1.3 billion tonnes yearly, and expected to increase to almost 2.2 billion tonnes per year by 2025 (Hoornweg and Bhada-Tata 2012; Karak et al. 2012). On average developed and developing countries subsequently generate 1.43–2.08 kg and 0.3–1.44 kg per person daily (Karak et al. 2012). The Turkish Statistical Institute indicates that municipal waste generation in Turkey, per capita, was 1.17 kg/year in 2016 (TÜİK 2016). This figure could differ from region to region nationwide according to the development level.

* Corresponding Author: Tel: +90 (282) 2502453 Fax: +90 (282) 2509924
E-mail: naydin@nku.edu.tr (Aydın N)

Gönderim Tarihi / Received : 04/10/2018
Kabul Tarihi / Accepted : 19/09/2019

For instance, municipal waste generation in Ankara, Istanbul and Izmir was subsequently 1.14 kg/day/person, 1.3 kg/day/person and 1.32kg/day/person in 2016 (TÜİK 2016). It was also stated by Tinmaz and Demir (2003) that in Corlu, 170 tonnes of municipal solid waste are generated each day, corresponding to 1.15 kg per capita per day.

It is important that municipalities provide the necessary services in the field of solid waste management, both in terms of protecting public health and not damaging the image of that region. The effectiveness of the solid waste management system is considered to be the success of the management. Waste management and recycling activities have a complex and multifaceted mechanism that requires comprehensive and integrated approaches. Integrated waste management is a systematic approach to municipalities to optimise their waste management practices and to maximise environmental benefits at the lowest possible cost (Ishizaka and Lopez 2019). This approach is based on an integrated perspective of waste and secondary resource (recycling) management systems in environmental, economic, political, institutional and social areas. The establishment of a strong solid waste management system in a region and the sustainability of this system are among the most important objectives of the regional authority. In Turkey, a number of studies based on an integrated approach have increased in recent years. For instance, Coban et al. (2018) created 8 solid waste disposal scenarios in Istanbul and evaluated them via 7 criteria according to the opinions of the experts from the field by using several multi-criteria decision making methods. Likewise, Arıkan et al. (2017) studied 10 disposal alternatives of solid waste and evaluated them via 18 criteria which were determined by Istanbul Environmental Management Industry and Trade Cooperation Limited. Another recent project was conducted by Erses-Yay (2015) who determined the environmental aspects of an efficient municipal solid waste management system through life cycle assessment methodology in Sakarya.

In a study conducted by the United Nations Urbanisation Programme, the current situation of solid waste management in many parts of the world was analysed. Accordingly, solid waste collection and controlled disposal rate was found to be 50% in low-income cities (Scheinberg et al. 2010). Solid waste generation is thought to increase in parallel with the increasing population. It is seen that the developing regions have failed to develop a waste management system in parallel with the increasing amount of solid waste. For example, the total population of India has increased from 500 million to 1300 million in the last 50 years (URL-1 2019). In addition, improved living conditions in parallel with the economic growth and industrialisation in this region resulted in an increase in the amount of solid waste (Banerjee et al. 2018). However, in many regions of India, the solid waste management system has a moderate level of development and recycling success has been at a standard level (Banerjee et al. 2018; Shah and Shah 2018). In rapidly developing regions, it is essential that existing solid waste management to be comprehensively addressed and evaluated to establish a strong solid waste management system and make a smooth transition to sustainable resource management.

When the studies in the solid waste literature are examined, it is seen that these studies produce results using old data which do not reflect the current situation in the field of waste management. They then compare these results mostly with other cities on a national scale (Chalmin and Gaillochet 2009; Hoornweg and Bhada-Tata 2012; Karak et al. 2012). Moreover, in the national solid waste management literature, the number of publications dealing with Ankara's solid waste management with a holistic approach is quite limited. One of the studies which deals with solid waste generated in Ankara was produced by Ozeler et al. (2006). Another one presents the co-evolution of socio-technical heterogeneity and waste governance by means of urban political ecology in Ankara (Tucaltan 2017).

In this study, Stan (Substance Flow Analysis) software was used to construct a Materials Flow Model and to make an analysis of the waste management system of Turkey's one of the most advanced provinces, Ankara.

Materials Flow Analysis (MFA) is a systematic assessment of the flows and stocks of materials within a system defined in space and time (Brunner and Rechberger 2004). MFA have been used in various areas so far in the literature, such as environmental impact assessments (Saurat 2006), environmental policy decision making (Hendriks et al. 2010), river water quality assessments (Schaffner et al. 2006), waste management (Allesch and Brunner 2015; Allesch and Brunner 2017) and selecting sustainable sanitation technology options (Yiougo et al. 2011). In these studies, MFA was adopted to gain a critical view on environmental management including water, wastewater and waste management in a city or a country. It is applicable for evaluating, for instance, the environmental soundness of sanitation alternatives by calculating and making comparison the amount of emission or waste flows within the city for each technology options. In this way, decision makers can choose the best options which do not pollute air and allow recycling.

There are two important studies published recently using the Stan software. One of these is the study of the current solid waste management in the Kingdom of Bahrain, which is a rapidly developing island country exposed to strong globalisation (Al Sabbagh et al. 2012). In this study, material flow diagrams of the Bahrain's waste and secondary resource management systems have been established and the results were compared with low, middle and high income cities in other parts of the world. Another study was carried out in Bishkek, the capital of Kyrgyzstan (Sim et al. 2013). In this study, the existing solid waste management system was determined using the indicators method and the results were compared with twenty different cities (Wilson et al. 2012). The focus of the study was to determine the nature and extent of the recycling activity in the city after the end of the state-supported recycling system.

The wastes to be handled in the project are all types of solid waste generated by households and other sources, such as shops and offices. In this scope, commercial and industrial wastes from industry and large volume construction and rubble wastes are excluded.

This study aims to analyse both the public and private activities in waste management by using an internationally accepted method for the reuse and recycling of valuable resources in waste in Ankara. It specifically focuses to;

1. Determine the stages which solid wastes pass through in the province, such as collection, treatment and disposal, as a comprehensive picture,
2. Reveal the waste flow through these stages,
3. Present the data and information gaps and to discuss how these gaps could be filled to strengthen to whole management system.

The results of this study are important as they will help stakeholders to improve their understanding regarding the areas of investment.

2. Methodology

MFA is the quantification and assessment of matter (water, food, excreta, waste, wastewater, etc.) and substances (carbon, phosphorus, etc.) mass flows and processes, in a system (city, country, etc.) during a defined period. The principle of MFA is based on the law of matter conservation; flows are expressed in tonnes/year or in tonnes/capita/year. This project takes account municipal wastes from houses, commercial and industrial wastes produced from other sources in the project area (such as shops and offices) and small scale construction and demolition wastes generated during the renovation works in houses. This will exclude commercial and industrial waste from the industry and large volumes of construction and demolition wastes.

The methodology of this study is based on MFA by adopting Stan software which is a MFA software tool developed by the Technical University in Vienna (URL-2 2009). Stan is a user friendly software tool that can be used by entering the known data in a model and missing data will be estimated on the basis of the "mass-balance" principle. The first step of MFA consists in the identification of the key material flows and the setting of "system boundaries". In static modelling "transfer coefficients" are used to redistribute the inflows over outflows. Figure 1 shows an example model with the data;

1. Raw material is 100 tonnes/annum (t/a) (fixed value for this flow) and
2. Recycling rate is 70% (transfer coefficients that the recycling flow equals 0.7 of the product inflow).

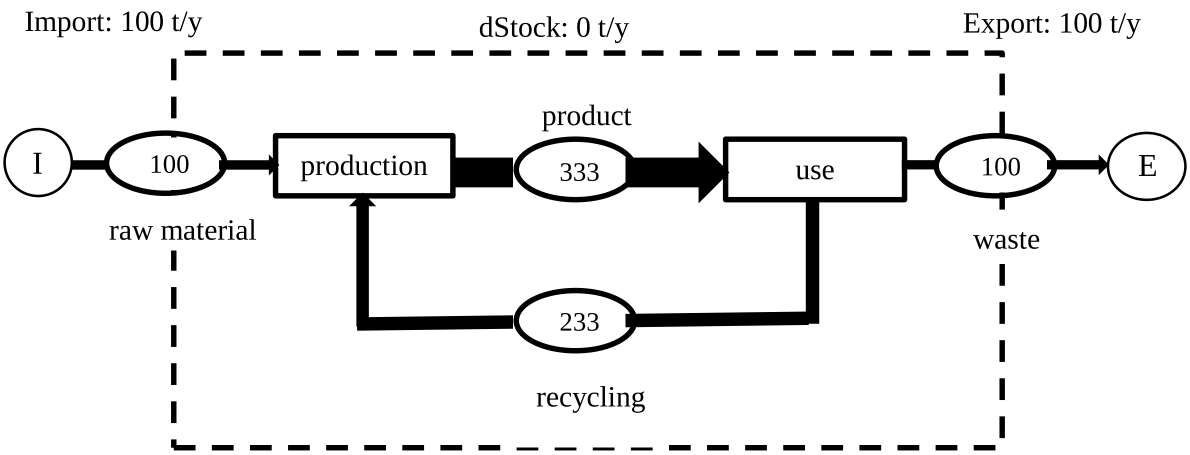

Figure 1: A Basic Stan Model (Cunningham and Cunningham 2015)

The main idea behind Stan is the combination of all necessary features of a MFA in one software product: modelling, data management, calculations and graphical presentation of the results. MFA is the systematic assessment of flows and stocks of materials within a complex system. Stan is generally used simply for picturing mass flows of substances and arrows. This offers the advantage that the largest flows of materials can be recognised immediately.

A model of a system includes processes and flows. A process is a place where transformation, transport or storage activities of materials take place. Generally, processes are defined as black boxes, meaning that detailed information what is happening inside is not available or not taken into account. Only the inputs and outputs are of interest. Otherwise the process must be defined as a subsystem that contains more than one sub-process. Flows connect processes. If any of them cross the system boundary they are called import (I) or export (E) flows. The aim of MFA is to describe and analyse a system as simple as possible, but in enough detail to make the right decisions.

In this study, the Stan model helps to visualise the whole solid waste and recycling system in the project area. All solid wastes produced in the region are treated as system inputs, material flows are clearly shown along the system boundaries, and the system output forms sanitary landfills.

3. Solid Waste Management in Ankara

Ankara is the capital city of Turkey and the second largest city in the country after Istanbul. It is located at the heart of both Turkey and Central Anatolia (Figure 2). As it is also one of the most developed provinces of Turkey, solid waste management service of the province is well facilitated. In Ankara, approximately 4500 tonnes of solid waste is collected every day (this amount is 4520 tonnes per day in summer months and 4530 tonnes in winter months) (URL-3 2017).

Approximately 2500 - 3500 tonnes/day of waste is disposed of Mamak Solid Waste Landfill Site. With the capacity improvement that is planned to be done in this landfill site, the waste generated from compost facilities in the vicinity could also be disposed of the Mamak Solid Waste Landfill Site (URL-4 2017). There is also another landfill in Ankara, called Sincan Landfill Site which also accepts medical wastes to be disposed of specially designated areas located nearby.

A biogas plant, which is located in the Sincan-Cadirtepe district, is operated by animal manure and it produces 22.66 MW equivalent power. It means that the plant could meet the daily electrical energy requirement of almost 24 thousand people with an average of 78 GWh electricity generation (URL-5 2018).

Private sector has a large share in solid waste management in Ankara. There are 5 transfer stations run by private sector in the province. In addition, the existing pre-treatment plants (mechanical separation, compost, bio-methanisation units) in the province are operated by private sector.

Figure 2: Map of Ankara

4. Materials Flow Model for Ankara

The flows of waste in the system were calculated and represented in the Stan model. The Stan software requires that all data streams be identified and quantified by entering existing data into the programme. Non-existent data can be calculated by using the mass correlation and the data associating feature of the programme as mentioned in Methodology. Existing data were collected from the sources such as:

1. Ankara Province Environmental Report (URL-4 2017),
2. National Waste Management and Action Plan 2023 (URL-6 2018) and
3. Environmental Reports (URL-3 2017).

Figure 3 shows the stages which the collected solid wastes in Ankara go through and it also presents how the amounts of waste get diverted by using the data in 2017. As seen from Figure 3, the waste passes through sieves at mechanical recycling units, after being accumulated at transfer stations. Then they are separated as below-sieve and above-sieve materials according to the magnitude of waste particules.

Below-sieve materials, mostly composed of organic wastes and fine materials, are transferred to biogas plant. Biogas conversion engine is used to produce electricity from this material. Then the remaining mass is sent to the compost plant mixed with other garden wastes. The compost is used in afforestation and landscaping.

On the other side, above-sieve materials are either transformed to refuse-derived fuel (RDF) or sent for thermal process. As known, RDF is an alternative type of solid fuel obtained from residual combustible material after municipal or industrial solid wastes, recoverable materials (plastic, glass, metal, etc.) are separated. This fuel with high calorific value is also used as fuel in cement factories and power generation plants (Lockwood and Ou 1993). The stock parameter called "Landfill" symbolises the two landfill sites in Ankara as mentioned in Solid Waste Management in Ankara.

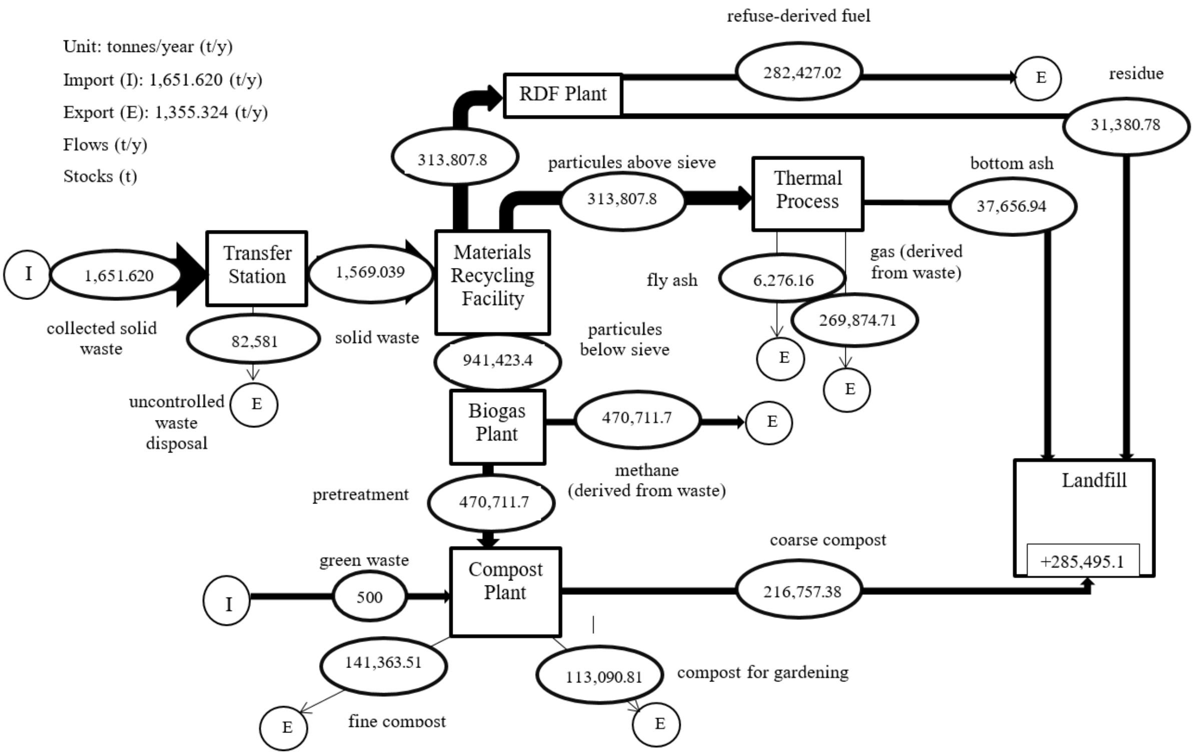

Figure 3: Materials Flow Model of Ankara (Stan Software)

The materials flow model developed in this study resulted that the amount of waste accumulated in the landfills of Ankara (as represented by the stock called "Landfill") is almost 286 thousand tonnes each year (Figure 3). This shows the possible requirement for capacity investment at Mamak Solid Waste Landfill Site, which is already on the agenda of city authorities. In Turkey, municipal wastes generally contain high biodegradable content. This is also reflected to the solid waste composition of Ankara. As it is seen from Figure 3, the waste flow which goes to the stocks of biogas and compost plants respectively is three times larger than the waste stream which is diverted for the RDF production and the thermal process. However the efficiency of recovery and recycling systems in any waste management system is directly related to the waste collection method. Figure 3 shows that there is a relatively important loss in the beginning of the system, as represented by the flow called "uncontrolled waste disposal" from transfer stations in Ankara. This fact illustrates that while solid waste management and recycling of solid wastes must be ensured on the one hand, the environmental impacts caused by the lost solid wastes due to uncontrolled waste disposal is needed to be eliminated throughout the province. This could also prevent the loss of resource for electricity and compost production by increasing the efficiency of the whole system.

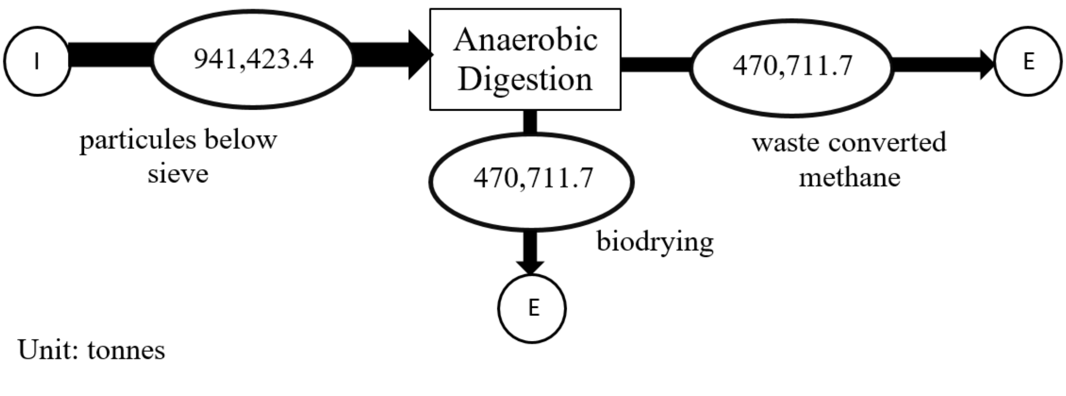

Figure 4: Biogas Sub-system of Materials Flow Model

Figure 4 shows the details of the sub-system of the stock parameter named "Biogas Plant" in Figure 3. As it is seen from the materials flow balance, the amount of waste recovered to methane is the same as the amount of waste transferred to the compost plant while there is no significant loss in the sub-system.

Figure 5 shows the details of the sub-system of the stock parameter called "Compost Facility" in Figure 3. Below-sieve particules passing through dewatering and advance composting stages get combined with other garden wastes and then they are reused in parks and gardens for afforestation purposes.

Figure 4 and Figure 5 also show that almost 470 thousand tonnes of solid waste is being used for methane production and more than 400 thousand tonnes of compost is being produced each year in Ankara. This presents that the existing solid waste management system of the province is highly based on bio-recycling and energy recovery.

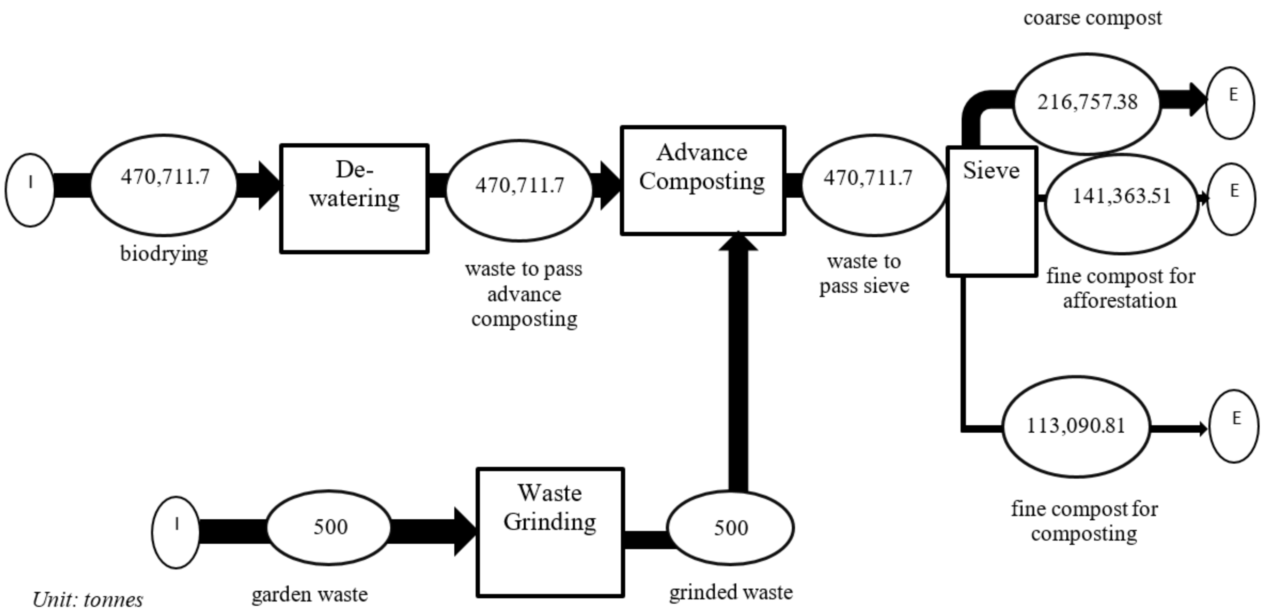

Figure 5: Compost Sub-system of Materials Flow Model

5. Conclusion

The method used in this study, MFA, allows identifying problems and quantifying the impact of potential measures on resource recovery and environmental pollution. It can be used to compare different technology alternatives regarding their environmental and economic impacts in order to have critical views on them. This basically helps decision-making for choosing within different options as it provides capability to evaluate environmental soundness of different options. This makes MFA a very useful tool, especially in developing countries with limited technical and financial resources. It can still be difficult to feed material flow model with required data because of the high amount of data needed. In this case, using the method of "eliciting expert judgement" could provide translation of stakeholder knowledge (experts from regional development agencies, provincial directorate of the municipality, academia, private-public sector cooperation, etc.) into probabilities for real values.

One of the most challenging obstacles in the field of solid waste management especially in developing cities is the lack of current and detailed data. This could lead to misleading assumptions and results, as well as false actions. There are two important advantages of using MFA in such studies. First, with this method, the data will be handled within a standard framework. Secondly, the use of a standard method for the assessment of solid waste management in any region and the spread of these studies in different regions will give researchers the ability to compare their results. As it is known, the use of different terminology in the solid waste literature causes the results obtained for different regions not to be compared or misinterpreted (Ciplak 2015). For example, when the values expressed by "amount of solid waste" are compared for cities A and B, it may be concluded that city A produces more solid waste. However in City A, waste from shops and offices is included in the scope of "solid waste", while in City B, this category of waste is totally excluded. In this sense, it is important that the evaluations are based on a standard method and carried out within a framework, as a solution for such problems. MFA has become ready for widespread use with the examples in the literature and reached maturity. There is a number of international study adopted this methodology to address weak points in the development of solid waste management of a city that determines the priority of the next steps (Wilson et al. 2012; Wilson et al. 2013).

If this method is widely applied as a standard methodology in the solid waste management of Turkey, it will ensure systematic comparison of solid waste management performances of both high- and low-income cities. Thus, a robust solid waste management system that meets the needs of communities and contributes to sustainable resource management could be established.

Acknowledgement

The author extends her thanks to Dr. Costas Velis, a specialist of waste-aware benchmark indicators and Dr. Joel Millward-Hopkins, Stan software professional from the University of Leeds, the UK for sharing their knowledge and experience.

References

Al Sabbagh M.K., Velis C.A., Wilson D.C., Cheeseman C.R., (2012), *Resource management performance in Bahrain: a systematic analysis of municipal waste management, secondary material flows and organizational aspects*, Waste Management and Resource, 30(8), 813–824.

Allesch A., Brunner P.H., (2015), *Material Flow Analysis as a Decision Support Tool for Waste Management: A Literature Review*, Journal of Industrial Ecology, 19(5), 753-764.

Allesch A., Brunner P.H., (2017), *Material Flow Analysis as a Tool to improve Waste Management Systems: The Case of Austria*, Environmental Science & Technology, 51(1), 540-551.

Arıkan E., Şimşit-Kalender Z.T., Vayvay O., (2017), *Solid waste disposal methodology selection using multi-criteria decision making methods and an application in Turkey*, Journal of Cleaner Production 142(Part 1), 403-412.

Banerjee P., Hazra P., Ghosh P., Ganguly A., Murmu N.C., Chatterjee P.K., (2018), *Solid Waste Management in India: A Brief Review*, Waste Management and Resource Efficiency'nin İçinde (Ghosh S.K., Ed.), Springer, ss.1027-1049.

Brunner P.H., Rechberger H., (2004), *Practical Handbook of Material Flow Analysis*, International Journal of Life Cycle Assessment, 9, 337–338.

Chalmin P., Gaillochet C., (2009), *From Waste to Resource: World Waste Survey 2009*, Economica Ltd., Paris.

Ciplak N., (2015), *Assessing Future Scenarios for Healthcare Waste Management Using a Multi- Criteria Decision Analysis Tool: A Case Study In The Turkish West Black-Sea Region*, The Journal of Air and Waste Management Association, 65(8), 919-929.

Coban A., Fırtına Ertis I., Ayvaz-Çavdaroğlu N., (2018), *Municipal solid waste management via multi-criteria decision making methods: A case study in Istanbul, Turkey*, Journal of Cleaner Production, 180, 159-167.

Cunningham W.P., Cunningham M.A., (2015), *Principles of Environmental Science*, Universiteit Leiden, https://www.studeersnel.nl/nl/document/universiteit-leiden/analytical-methodologies-and-tools/practicum/exercise-on-material-flow-analysis-with-stan/274396/view, [Accessed 18 September 2018].

Erses-Yay A.S., (2015), *Application of life cycle assessment (LCA) for municipal solid waste management: a case study of Sakarya*, Journal of Cleaner Production, 94, 284-293.

Hendriks C., Obernosterer R., Müller D., Kytzia S., Baccini P., Brunner P.H., (2010), *Material Flow Analysis: A tool to support environmental policy decision making. Case-studies on the city of Vienna and the Swiss lowlands*, the International Journal of Justice and Sustainability, 5(3), 311-328.

Hoornweg D., Bhada-Tata P., (2012), *What a waste: a global review of solid waste management*, Urban Development Series Knowledge Papers, World Bank, Washington D.C., https://openknowledge.worldbank.org/handle/10986/17388, [Accessed 30 March 2018].

Ishizaka A., Lopez, C., (2019), *Cost-Benefit AHPSort for Performance Analysis of Offshore Providers*, International Journal of Production Research, 57(13), 4261-4277.

Karak T., Bhagat R.M., Bhattacharyya P., (2012), *Municipal solid waste generation, composition, and management: the world scenario*, Critical Reviews in Environmental Science and Technology, 42, 1509–1630.

Lockwood F.C., Ou J.J., (1993), *Review: Burning Refuse-Derived Fuel in a Rotary Cement Kiln*, Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 207(1), 65-70.

Ozeler D., Yetis U., Demirer G.N., (2006), *Life cycle assessment of municipal solid waste management methods: Ankara case study*, Environment International, 32(3), 405-411.

Schaffner M., Bader H.P., Koottatep T., Scheidegger R., Schertenleib R., (2006), *Using a Material Flow Analysis Model to Assess River Water Quality Problems and Mitigation Potentials - A case study in the Thachin River, Central Thailand*, 3rd APHW Conference: Wise Water Resources Management Towards Sustainable Growth and Poverty Reduction, October 16-18, Bangkok, Thailand.

Saurat M., (2006), *Material Flow Analysis and Environmental Impact Assessment Related to Current and Future Use of PGM in Europe*, Master of Science Thesis in the Master Degree Programme, Industrial Ecology, Chalmers University of Technology, Goteborg, Sweden.

Shah K.V., Shah D.D., (2018), *An Approach Towards Sustainable Municipal Solid Waste Management in India*, Waste Management and Resource Efficiency'nin İçinde (Ghosh S.K., Ed.), Springer, ss.1067-1076.

Scheinberg A., Wilson D.C., Rodic L., (2010), *Solid Waste Management in the World's Cities: Water and Sanitation in the World's Cities 2010*, http://www.waste.nl/sites/waste.nl/files/product/files/swm_in_world_cities_2010.pdf, [Accessed 30 August 2019].

Sim N.M., Wilson D.C., Velis C.A., Smith S.R., (2013), *Waste management and recycling in the former Soviet Union – case study of Bishkek, Kyrgyz republic (Kyrgyzstan)*, Waste Management Resources, 31, 106–125.

Tinmaz E., Demir I., (2006), *Research on solid waste management system: To improve existing situation in Çorlu Town of Turkey*, Waste Management, 26(3), 307-314.

Tucaltan G., (2017), *Metabolic Urbanization of Waste in Ankara: A Governance Perspective*, Eburon Academic Publishers, Delft The Netherlands, 280ss.

TÜİK, (2016), *Databases, Environment Statistics*, http://www.tuik.gov.tr/PreTabloArama.do?metod=search&araType=vt, [Accessed 30 August 2019].

URL-1, (2019), *Population of India*, Ministry of Statistics and Programme Implementation, UN (World Population Prospects 2017), http://statisticstimes.com/demographics/population-of-india.php, [Accessed 30 August 2019].

URL-2, (2009), *STAN - Software for Material Flow Analysis*, Institute for Water Quality and Resource Management, Wien, https://iwr.tuwien.ac.at/en/resources/home/, [Accessed 19 December 2019].

URL-3, (2017), *Çevre Durum Raporu (2016 Yılı Özeti - İller)*, Çevre ve Şehircilik Bakanlığı, Çevresel Etki Değerlendirmesi, İzin ve Denetim Genel Müdürlüğü, http://webdosya.csb.gov.tr/db/ced/dokumanlar/iller-ozet--8230-5238-20180201170654.pdf, [Accessed 30 March 2018].

URL-4, (2017), *Ankara İli 2016 Çevre Durum Raporu*, Ankara Valiliği Çevre ve Şehircilik İl Müdürlüğü, http://webdosya.csb.gov.tr/db/ced/editordosya/Ankara_icdr2016.pdf, [Accessed 30 April 2018].

URL-5, (2018), *Sincan Çadırtepe Biyokütle Enerji Santrali*, http://www.enerjiatlasi.com/biyogaz/sincan-cadirtepe-biyokutle-enerji-santrali.html, [Accessed 18 September 2018].

URL-6, (2018), *Ulusal Atık Yönetimi ve Eylem Planı 2023*, Çevre ve Şehircilik Bakanlığı, http://webdosya.csb.gov.tr/db/cygm/haberler/ulusal_at-k_yonet-m--eylem_plan--20180328154824.pdf, [Accessed 30 March 2018].

Hoornweg D., Bhada-Tata P., (2012), *What a Waste: A Global Review of Solid Waste Management*, The World Bank Urban Development Series – Knowledge Papers, https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf, [Accessed 30 August 2019].

Wilson D.C., Rodic L., Scheinberg A., Velis C.A., Alabaster G., (2012), *Comparative analysis of solid waste management in 20 cities*, Waste Management Resources, 30(3), 237–254.

Wilson D.C., Velis C.A., Rodic L., (2013), *Integrated Sustainable Waste Management In Developing Countries*, Waste Management Resources, 166, 52–68.

Yiougo L.S.A., Koanda H., Wethe J., Luthi C., Yapo O., Dapola E.D., (2011), *The method of material flow analysis, a tool for selecting sustainable sanitation technology options: The case of Pouytenga (Burkina Faso)*, WIT Transactions on Ecology and the Environment, Vol. 145, 671-680.