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RESEARCH PAPER

Material flow analysis for household waste

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A B S T R A C T:
Material flow analysis (MFA) is a tool used for a sustainable quantification and assessment of matter and substances during a specific period of time. The MFA system is mathematically controlled by a simple mass balance which defines all inputs, outputs and stocks of a process. Waste management in Erbil city has become the main problem and increased the generation rate per capita per year with economic growth and changing lifestyle. The current study aims to apply MFA for household waste in Erbil city to obtain a better, systematic waste management. The process model includes all input and output flows of household wastes and it provides a better management in household waste in the city. The total import of the household waste is 1.62 ton/year that is divided into four parts which are 1.23 tons/year is for kitchen waste (organic, combustible and incombustible), 0.03 tons/year for garden waste, and 0.03 tons/year for other waste and 0.33 for stocks material.

KEY WORDS: Material flow analysis (MFA), household waste, recycling, Erbil governorate
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1.INTRODUCTION :

According to Tran et al., (2018), identified that flow and stock materials can be systematically analyzed by MFA that is based on space and time for the systems. The substance flow analysis is defined based on the MFA which represents substances and goods. The good stands are referring to the waste, sludge cars while, and substance stands are referring to the gas material such as nitrogen and phosphorus. The fundamental principles of MFA are should be the input equal to the output that is retuned in years ago by Greek Philosophers (Vidal, 1985). It means that the input materials have balanced with output materials (Brunner and Ruchberger, 2004).

The quantify stocks and flows substances in the modern system are analyzed through MFA process (Condeixaet al., 2017, Cencic and Rechberger, 2008). It works based on the mass balance of input and output. The mass that came to the MFA system is accumulated and some leave the system (Bureecam, et al., 2018). Urbanization and economic growth are increasing the amount of solid waste generation in Erbil city. All waste production in the city is collected and directly disposed to the landfill site that is without any appropriate treatments and recycling of the waste. The landfill is not referring a sanitary landfill since, all combustible and incombustible wastes are mixed together without any segregation and treatments. The compositions of the solid wastes are mostly consisting of organic waste which is coming from food waste in Erbil city. Therefore waste recycling is giving the problems of waste management in the Erbil city. Composting is an important method for the biodegradable solid wastes (Aziz, et al., 2011). MFA has been widely used for environmental issues, especially in

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management of waste material. MFA can be used for policy of the waste management. In this research, MFA used for household waste in Erbil northern Iraq that is to determine both out and input flow material in the household to obtain better organize waste management.

In this paper, MFA was aimed for the quantification and identification of input and output of household waste so as to achieve a better systematic management of household waste. The application of Material Flow Analysis (MFA) in this study is relevant in monitoring waste flows and substances within the model. In addition, MFA is looking for finding the flow waste in the model for management of the household waste and determine input and out flows in household waste of Erbil city. The data is obtained from previous studies and researches.

2. MATERIALS AND METHODS

2.1. Study Area & data collection

Erbil city is the capital of Kurdistan region northern Iraq situated at 36.1901° N, 43.9930° E. It has a population of more than one million citizens (figure 1). The solid waste generation is 0.654 kg per capita per day in 2010 in Erbil city (Aziz et al., 2011). Table 1 shows the data of solid waste components for a single family that is contains 5 persons in Sarbasti quarter in Erbil city for one week duration. Considering one family represent all methodologies that needed to be taken into account in determination of generation rate of household wastes. Samples were collected in plastic bags. Each plastic bag weighed alone for each day during one week. The components of solid waste and its generation rate (GR) determined during one week for a five members of the family. Based on the following equation (Metcalf & Eddy, 2003):

$$\text{Generation rate (GR)} = \frac{Total\ solid\ waste\ (gm)}{No.of\ persons * period(day)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Figure 1 Location of Erbil city map

Table 1 Components and generation rate of solid waste for a household in Erbil city

Period (Day)	No. of person	Food (gm)	Paper(gm)	Metal (gm)	Plastic (gm)	Glass (gm)	Cloths (gm)	Total weight (gm)	GR Kg/cap.day	Combustible (gm)	Incombustible (gm)
	5	5936	413	162	191	304	383	7389	1.4778	987	466
	5	2260	29	…	141	154	354	2938	0.5876	524	154
	5	2648	150	…	57	….	160	3015	0.603	367	0
	5	3522	238	86	52	354	57	4309	0.8618	347	440
	5	4290	581	…	18	84	245	5218	1.0436	844	84
	5	2152	265	459	43	479	27	3425	0.685	335	938
	5	2691	612	…	829	150	500	4782	0.9564	1941	150
Total		23499	2288	707	1331	1525	1726	31076		5345	2232

According to the table 1, the average generation rate is 0.887 kg per capita per one day. It is indicated that each person in Erbil city produces 0.887 kg of solid waste per one day. The household solid waste comes from organic waste (food waste) from kitchen, combustible (plastic, paper and cloth) and incombustible (metal and glass) wastes. The total food waste is 23.499 kg per week. In addition, the total combustible waste (paper, plastic and cloth) is 5.345 kg/week while the total amount of incombustible waste (metal and glass) is 2.232 kg per week. Food waste generates majority of wastes from households which is 23 kg/week (about 75% of total waste. Figure 2 illustrates the amount of wastes generates during one week in kg. Total waste generated from the household family is 31.076 kg per week.

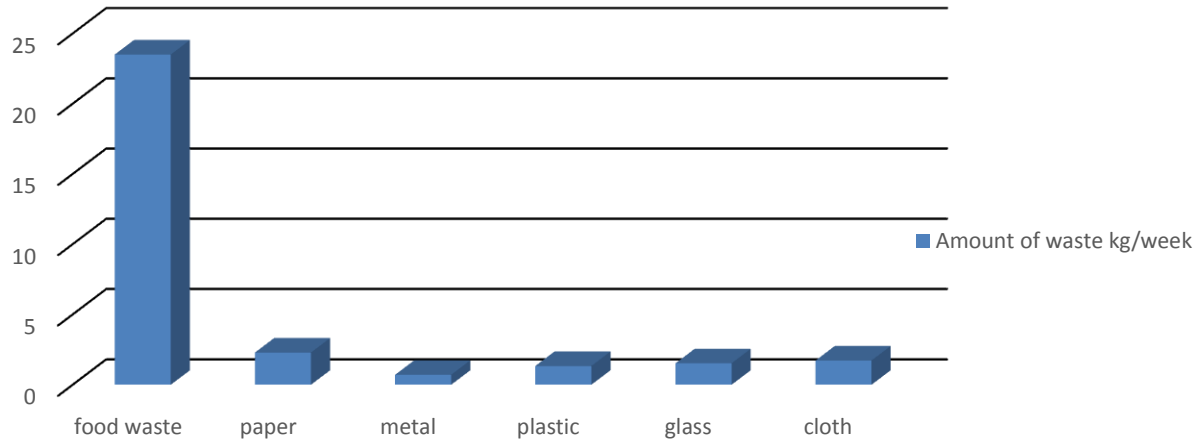

Figure 2 shows the waste generation from household in Erbil city

2.2 Mathematical implementation and calculation algorithm of MFA

During starting calculation to compute unknown of a graphical models created by STAN, it has to be transformed automatically into a mathematical models using four types of equations as follows:
Balance equation: ∑input= ∑output + change in stock
Transfer coefficient equation: output x = transfer coeff. to output x ∑inputs

Stock equation: stock Period i+1 = stock Period i + change in stock Period i
Concentration equation: mass substance = mass good · concentration substance
The above equations contain measured, unknown and exactly known variables
To enhance the accuracy of measurements, at least one equation should be known with one measured variable data reconciliation. To obtain this goal, a Gauss-Jordan elimination method is proposed by (Madron, 1977) for the original linear constraint matrix. Necessary corrections of the measurements are check by statistical tests which can be explained by random errors or gross errors. Consequently, for the unknown quantities, improved values are used to calculate the quantity. The corresponding uncertainties are determined with the method of error propagation.

2.3 MFA for household waste management in Erbil city

The below flow analysis is demonstrated by STAN 2.6.801 software (figure 3). It illustrates the material flow analysis MFA for waste in households. The input and output wastes are illustrates. The majority of solid waste in households in Erbil city is organic waste based on data of this study and other researchers in literature review. The input flow of household waste mainly generated from kitchen, garden, bathroom and others. The output flow is the system is mostly organic, combustible (plastic, paper and cloth), incombustible (metal and glass), and wastewater and methane gas emission.

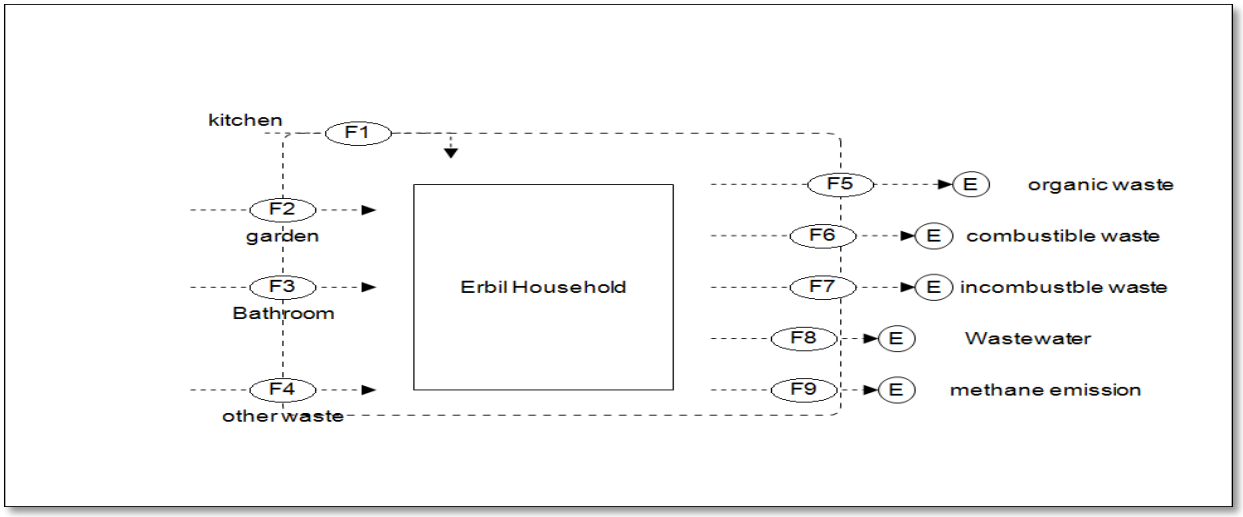

Figure 3 shows the MFA input and output household waste in Erbil city

2.4 MFA processes (input and output data with STAN)

STAN is free software used for material flow analysis. It is based on mass balance principles to input data (Tang and Brunner, 2013, Laner et al., 2014). Figure 4 and 5 show the Material Flow Analysis (MFA) for household system in Erbil for 2020. It illustrates the total input and output of the system and the source of waste contributed from kitchen, bathroom, garden and other wastes, from kitchen, organic waste, combustible and incombustible wastes were generated. The total input of the system is 1.62 tons per year. The organic waste which is food waste contributed the highest amount of waste with 31.076 kg per week i.e. %75 of waste generation is food waste. Followed combustible is about (%17), incombustible (%7.18) and garden waste. It is supported by other studies that major component of municipal solid waste in Erbil city is food waste (%79) (Aziz et al., 2011). Since all activities occurs in the kitchen such as cleaning, cooking and waste generation (organic, combustible and incombustible wastes), so the total input flow for kitchen in the MFA system is 1.23 tons per year. The input flow for organic waste, combustible and incombustible waste are 0.7, 0.3 and 0.23 tons per year. The rest of the wastes refer to garden and other wastes. The output waste of organic waste can generate home composting. A part of home composting (0.3 tons per year) can be used back for gardening and another portion (0.4 tons per year) will disposed to landfill resulting in degradation of organic materials. High concentration of heavy metals inside compost result in harmful compost for

planting and animals (Abdii and Schlosser, 2019) solid waste On the other hand, combustible waste can be treated by thermal treatment such as gasification and incineration treatment (0.3 tons per year), while the final production of the treatment (fly ash) go to landfill. Moreover, the input flow for incombustible waste is 0.23 tons per year. The output of incombustible material can be separated and recycled as a raw material for industrial using (0.76 tons per year) while other part (0.15 tons per year) disposed to landfill site. For the input flow of water supply system, 279 liter per capita per day estimated according to literature review and general directorate of water and sewerage in Erbil city (GDWS and Abdullah et al., 2020). The input water supply is 509.51 m3 per year is used as water consumption use for a household system which is calculated as below. The output flow produced wastewater, which is about 80% of water consumption (406.61 m3 per year). The wastewater generation is discharged into the environment directly. In addition, in the landfill site methane gas is estimated to be emitted into the air which is produced from the waste disposal as a result of waste accumulation (Qayyum & Norahikin, 2017 and Ghani et al., 2019).

After conducting all input and out flow of waste. The software calculates and analysis the system for a given period of time with showing no error in the calculation part of the system as in the bottom box all layers are in blue color with right description of each of them(Yoshida et al., 2009) (figure 6). In this study, MFA is conducted for waste management in household in Erbil city.

Water consumption L capita/day= 279
Water consumption for a family with 5 person/ year= 279*5*365/1000= 509.175 m^3/year

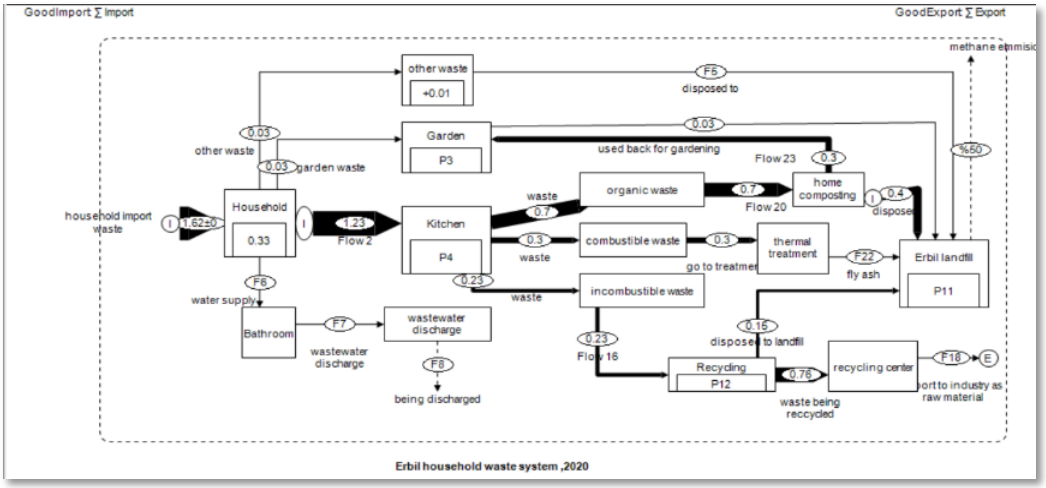

Figure 4 MFA system analysis (mass flow tons/year)

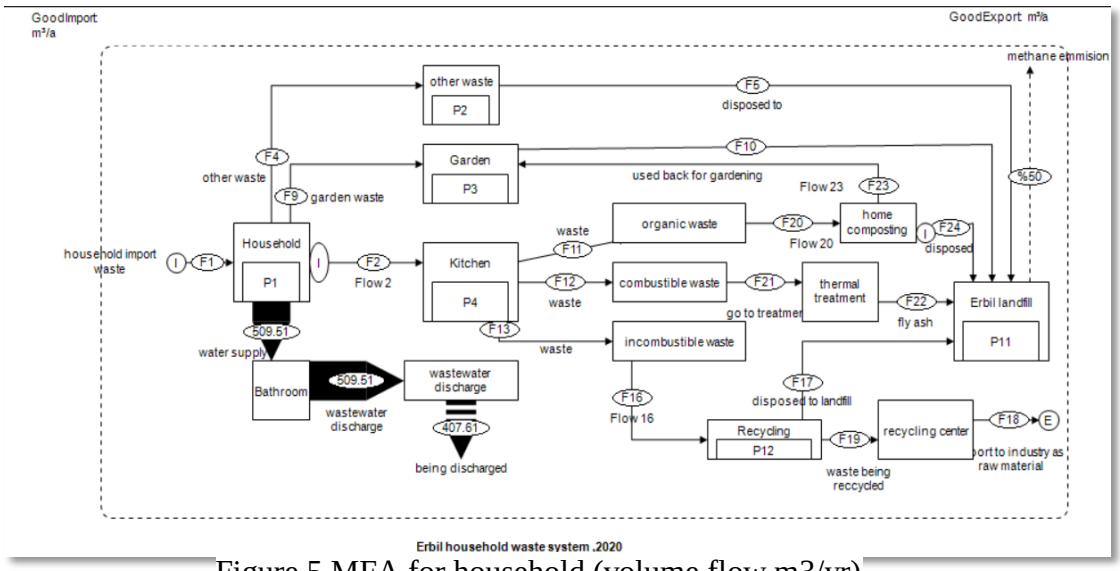

Figure 5 MFA for household (volume flow m3/yr)

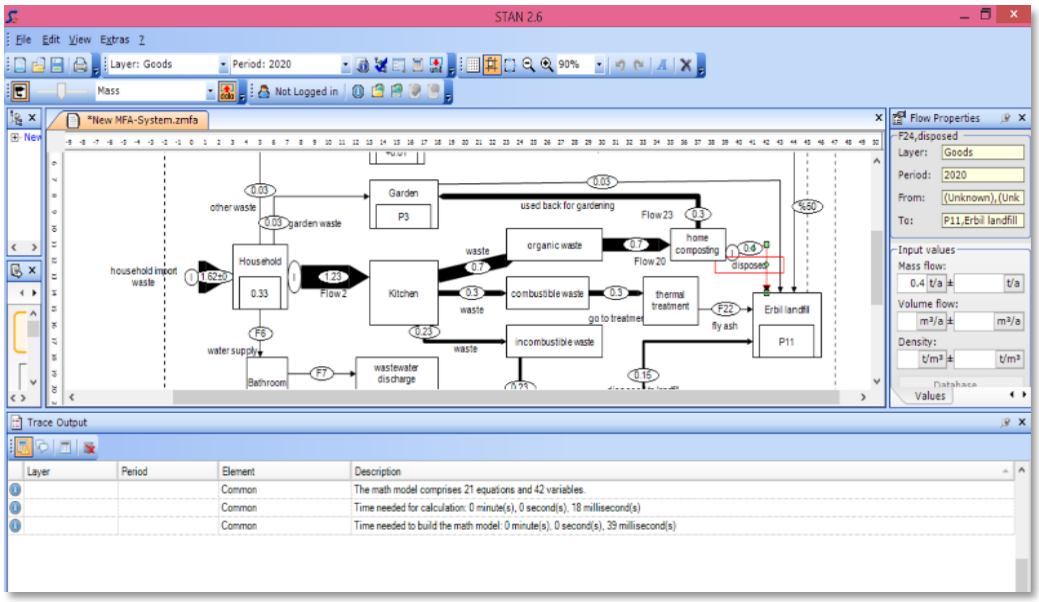

Figure 6 MFA calculations with no error in the system

3. CONCLUSION

In this study the following concludes have been determined. MFA applied for the assessment of waste management in Erbil city. Basic principles of mass balance conservation are used to define the processes of the system.

1. It is concluded that majority of household waste generation comes from combustible and non - combustible.
2. The organic waste (food waste) is covers about 75%, combustible is about 17% and incombustible is 7%.
3. The total import of the household waste is 1.62 ton/year that is divided into four parts which are 1.23 tons/year is for kitchen waste (organic, combustible and incombustible), 0.03 tons/year for garden waste, and 0.03 tons/year for other waste and 0.33 for stocks material.
4. The household requires to be minimized from the quantity of organic wastes.
5. Some of the materials can be separated from incombustible waste which can be used for as a raw material in the industrial.
6. Moreover, some parts of organic waste can be used in the home composting that is used for gardens and other large part is going to the landfill sites.
7. The MFA system has able to obtain the management of the household waste in cities in a more sustainable way.

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