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Hazardous wastes and waste generation factors for plastic products manufacturing industries in Turkey

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ABSTRACT

A project titled "Hazardous Waste Management in Compliance with European Union Environmental Regulations in Turkey" was carried out with the support of The Scientific and Technological Research Council of Turkey on behalf of the Ministry of Environment and Urban Planning in Turkey. In this project, several industries were examined for improving an internet based system called "Hazardous Waste Declaration System" (HWDS) and meeting the requirements of Turkey. Hazardous waste lists and hazardous waste generation quantities per unit manufacturing (hazardous waste generation factors, HWGFs) for the plastic product manufacturing industry were determined based on the data obtained from these studies. At the same time, declarations of hazardous waste generation quantity made by the organizations in this industry in 2009 and 2010 to HWDS and the literature data were evaluated and the range of HWGFs was created by assessing possible minimum and maximum quantities for each waste. This paper presents the results of the studies conducted in plastic product manufacturing industry in Turkey. The waste lists determined along with the HWGF ranges are presented. HWGFs for manufacturing processes in the plastic industries were calculated in the range of 11.5–100 kg t^{-1} in this study and can be used to calculate the amount of hazardous waste for other similar process in the plastic industries. Therefore, it is believed that the results of the study will be useful for determining the types and quantities and the management of hazardous wastes generated by similar plastic product manufacturing industries in the developing world.

1. Introduction

Hazardous waste has dangerous properties and exerts a harmful effect on human health or the environment. Management of hazardous wastes is one of the major environmental issues. Hazardous waste management requires accurate information on the amounts of different types of hazardous wastes. The lack of sufficient information on hazardous waste results in failure of their control and monitoring. Moreover, the known hazardous waste quantities are essential to determine waste prevention and minimization options for the industry. Therefore, industrial hazardous waste generation factors should be determined to establish a reliable waste inventory.

Hazardous waste generations and management options in different countries have been reported by numerous researchers. Hazardous waste generation and disposal options in China were reported by Duan et al. [1]; the quantity of generated hazardous waste has increased rapidly. In another study, hazardous wastes management options in three major industries in Chile were identified, classified, and quantified according to Chile's new regulation [2]. An evaluation of the hazardous waste management in Portugal is also made in terms of legislation framework, technologies applied and waste volume production [3]. In this paper, the legislation framework and new management methods for industrial hazardous waste were created and new organizations were reported. There are also other studies to characterize plastic

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waste management. For example, the information on recycling and disposal management options of agricultural plastics waste was investigated by Muise et al. [4]. Literature studies and all aspects of waste management options were discussed in their study, along with survey studies for implementation of recycling programs as well seeking information on practices and policies regarding plastics waste [4]. Another field survey study was performed by Sha'Ato et al. to generate a solid waste generation profile in a rapidly growing urban city in Nigeria [5]. Solid waste management planning options for this small city were then discussed. In the study by Meng et al., the factors affecting recycling programs were discussed for lowering the volume of plastic destined for landfills for the environmental horticulture firms. The results of this study offer useful knowledge for designing and implementing new or enhancing the existing recycling programs to local government and sustainable development organization for the environmental horticultural areas [6]. Current hazardous waste management system in Turkey was also investigated and reported in some recent studies [7–12]. In another study, a detailed survey for the estimation of waste factors from different manufacturing sectors was investigated to establish a reliable waste inventory study [13]. However, these studies are not detailed enough and mainly focussing on general waste control management.

The current type and quantity of the hazardous waste should be investigated to create the most efficient and the most economic management system for hazardous wastes in Turkey. The determination of the hazardous waste generation quantities per unit manufacturing (Hazardous Generation Waste Factor, HWGF) for leading industries is the first step of establishing a reliable hazardous waste management system. To meet these requirements, the project titled "Hazardous Waste Management in Compliance with European Union Environmental Regulations in Turkey" was carried out with the support of The Scientific and Technological Research Council of Turkey on behalf of the Ministry of Environment and Urban Planning (MEUP) in Turkey [14]. The long-term goal of the project is to contribute to the management of hazardous wastes in ways that are compatible with respect to hazardous waste regulations of Turkey that are developed in accordance with the EU compliance requirements. This goal will be accomplished by generating fundamental information that will provide the most efficient and cost effective hazardous waste management strategies for Turkey.

Priority sectors have been identified in terms of hazardous waste production in Turkey in the early stages of the mentioned project. A list of sectors producing hazardous waste in Turkey was created by using the outputs of LIFE HAWAMAN Project carried out by Ministry of Environment and Forestry, Turkish Statistical Institute data and Hazardous Waste Declaration System (HWDS) statements. The plastic product manufacturing sector, one of the priority sectors found in the list, was selected in this study.

This study involves detailed studies conducted for the determination of the types and quantities of the hazardous wastes obtained from the plastic product manufacturing industry which is one of the priority industries in terms of hazardous waste generation in Turkey. Within this scope, field studies were conducted in three different industrial enterprises, and their current manufacturing processes were investigated to cover all inputs and outputs. The types and quantities of hazardous wastes generated by the main manufacturing processes, sub-manufacturing processes and other activities were all determined. Through these data, the hazardous waste list and HWGFs based on the data obtained from field studies were determined for the afore-mentioned industry.

2. Methodology

2.1. Hazardous waste declaration system in Turkey

Turkish Regulation on Control of Hazardous Waste (RCHW) establishes a framework for hazardous waste management and follows the general rules given in European Council Directive on Hazardous Waste [15]. The waste codes used in RCHW are fully transposed from European Waste Catalogue. Hazardous waste producers in Turkey are required to declare hazardous waste quantity along with NACE (Statistical Classification of Economic Activities for European Community) codes according to RCHW in Turkey. HWDS is an official internet based program of the MEUP. For the classification of economic activities of waste generator, codes (NACE Rev. 2) were used in HWDS [16]. In this system, each waste generator has the option to select its own NACE Rev. 2 code from the list which was already integrated to the system. The system was improved so that the waste generators could enter their annual production capacities for each NACE Rev. 2 code. Listing of all possible expected wastes for each NACE Rev. 2 code was the goal in the project. It was also planned to select the wastes produced from these lists and enter each waste amount for a given year by waste generators. Thus, waste generators in Turkey could easily classify their wastes and declare the correct waste types. For the control of waste amounts declared in the system, it was aimed to develop waste generation factor specific for Turkey for every waste under each NACE Rev. 2 code to be used in HWDS. Waste generation factor showing "waste generation amount for unit production" is essential to control declared waste quantity in the system. Thus, waste declarations, increasing every year, can be controlled efficiently in terms of waste type and generation amount by MEUP.

2.2. Calculation of hazardous waste generation factors

Waste quantity from industrial activities, developed through the HWGFs, can be determined as industrial production capacity or quantity of production. HWGF helps to determine the amount of waste from various facilities on a regional basis or across the country. This information helps to plan recycling, treatment and disposal facilities for hazardous wastes. In addition, HWDS can also be used to check if the actual data declared are correct.

In this study, HWGFs were developed on capacity basis of the facility. HWGFs, developed based on production capacity, are calculated as per unit of output of the product or raw material used. It is noted that HWGF based on production capacity may vary from process to process. However, if the applied process is the same, the HWGF based on production capacity found in the literature for a given plant in any country can safely be used for other plants.

Plant manufacturing data were examined in order to determine the quantities of hazardous wastes in the related plants [14]. The hazardous waste generation factors were determined by the amount of hazardous waste produced divided by the annual product amount of related year in equation given below. Hazardous waste generation factors were given in both "kg waste t^{-1} product" and "kg waste/pieces product" throughout the study.

$$\mathrm{HWGF} = \frac{\text{The amount of hazardous waste (kg)}}{\text{The amount of annual product (t} - \text{pieces)}} \qquad (1)$$

Along with the waste lists determined in the studies, the ranges of HWGF value were determined using both literature review in this industry and declaration values in HWDS for years of 2009 and 2010. The range of HWGFs was determined by assessing possible minimum and maximum quantities for each waste.

3. Field studies and results

Current study was conducted by using three different plastic plants data in Marmara Region of Turkey. The area is heavily industrialized and located in the north-western part of Turkey. The manufacturing processes of these plants (Plant 1 is an injection moulding plant and Plants 2 and 3 are extrusion moulding plants) were examined during the field studies. The on-site field studies were carried out at certain periods of time. The manufacturing processes of the plants were examined, and data regarding the input and output quantities were taken for the processes examined. The process based waste generation factors were then calculated according to the information and observations obtained.

Plastic product manufacturing industry is given an economic activity code of "22.20-Manufacturing of Plastic Products" in a new version of the European Industrial Activity Classification System (NACE Rev. 2 2008) [16]. This code is a sub-class of manufacturing group of rubber and plastic products included in the section of the manufacturing industry (C.22), including the generation of intermediate products or final products by processing any new or used (for example recycled) plastic materials. Compression moulding, moulding by pulling and by rolling in, spraying – moulding, and casting are examples for these processes used.

3.1. Plant 1 – plastic switchgear manufacturing plant

Switchgears are devices that regulate the flow of electricity within an electrical system. They are generally used to prevent overloads and short circuits, and to de-energize circuits for testing and maintenance. Plastic injection moulding process is used during the manufacturing of these devices. Plastic injection is a method during which molten plastic is injected into an injection mould tool under high pressure conditions. The plastic cools inside the tool and takes the inverse form of the cavity machined into the tool.

The manufacturing process of a plastic injection part consists of the following phases.

- Closing: An injection machine consists of three main parts: closing unit, injection unit, and mould. Closing unit keeps the mould under pressure during injection and cooling. Simply, it is the unit which joins the two sides of the injection mould.
- Injection: During injection phase, the granulated plastic material is poured in the chamber on the injection unit. From there, it is taken into the cylinder heated by resistance heaters by means of a screw which is commanded by the electrical motor. The plastic material which has melted under heat and pressure is forwarded to the end of the cylinder via screw tightening process. Injection process starts when adequate material is taken to fill the mould. Melted plastic is sent into the mould by means of a nozzle at the end of the machine.
- Ironing: This process is applied for the part to be in the desired dimensions and to avoid several faults in its appearance. In this phase, the melted plastics are injected into the mould and filled the mould space by applying the pressure. The process continues until the plastic is solidified inside the mould.
- Cooling: This step causes hardening of the injected melted raw material inside the mould. The composite material which hardens in the mould can be taken out from the mould and used in almost every field of plastic material industry.
- Opening mould: Closing unit is opened such that both sides of the mould are parted.
- Removal: The finished part is removed from the mould by means of repellents.

Studies were conducted on the wastes in addition to the examination of the processes applied in the plant. The manufacturing data were examined with regard to hazardous wastes. These waste generation factors were calculated and its unit given as "pieces waste/pieces switchgear" and "kg waste/pieces switchgear".

3.2. Plant 2 – PVC profile manufacturing plant

The second field studied plant manufactures plastic construction materials (PVC Profile). Some of the white products which are obtained from the extruder are sent to the coating section. Here, the coating process is called as the lamination process. The lamination process increases the strength of the coated material, the resistance of colours compared to painted products. The plastic extrusion process of the plant was examined and the emerging hazardous wastes were determined.

3.3. Plant 3 – plastic material manufacturing plant

Manufacturing facilities in Plant 3 can be summarized in three main titles: thermoform printed and unprinted products, industrial plates, and compound & masterbatch. There are two lines for manufacturing in the plant; Ompia and Printing lines. The Ompia line manufactures solid plate using acrylic, polycarbonate and polyethylene terephthalate glycol material. The plastic extrusion process in the Ompia line of the plant was examined and the emerging hazardous waste was determined to be the "other still bottoms and reaction residues" (Code No: 070208). In the printing line, on the other hand, printing process is used for the thermoformed, namely thermally formed, cups. It is known that during the printing process, hazardous waste is generated during dye cleaning process. This waste is defined as "absorbents, filter materials (including oil filters not otherwise specified), wiping cloths, protective clothing contaminated by dangerous substances" (coded 150202).

The hazardous waste data were collected from field studies and HWDS and waste generation factors were accordingly calculated. The three main groups in the classification of the potentially hazardous wastes are generated in the plastic industry:

- "Wastes from Manufacturing, Formulation, Supply and Use (MFSU) of Plastics, Synthetic Rubber and Man-Made Fibres" under code no 0702
- "Wastes from Shaping and Physical and Mechanical Surface Treatment of Metals and Plastics" under code no 1201
- "Gases in Pressure Containers and Discarded Chemicals" under code no 1605.

The "Organic halogenated solvents, washing liquids and mother liquors" code no 070203 and above code no 070208 (other still bottoms and reaction residues) which are included under code 0702 (MFSU of Plastics, Synthetic Rubber and Man-Made Fibres) are the wastes observed in field studies conducted on plastic industry manufacturing switchgears. During the manufacturing process 'other still bottoms and reaction residues' are the most important wastes.

The wastes observed in field studies also included "spent grinding bodies and grinding materials containing dangerous substances" (code no 120120) under "Wastes from Shaping and Physical and Mechanical Surface Treatment of Metals and Plastics" (code no 1201), as well as "discarded inorganic chemicals consisting of or containing dangerous substances" (code no 160507) under

"Gases in Pressure Containers and Discarded Chemicals" (code no 1605).

In the manufacture of plastic products, code no. 07, 12 and 16 are listed in the process waste category. During the manufacturing process 'other still bottoms and reaction residues' are the most important wastes. Dyeing processes are used in industry as a sub-process. Therefore, code no. 08 as sub-process waste could be expected. In the list of non-process wastes, oil wastes, packaging waste, discarded equipment, batteries and accumulators, insulation materials and medical wastes are located.

Studies related to the determination of the wastes generated by the industry and the HWGFs were conducted by reviewing literature, field studies and HWDS. As a result, the list of the process wastes, sub-process wastes, and non-process wastes was generated as presented in Tables 1–5 with the determined HWGFs. HWGF values under HWDS were determined from the average values from HWDS by excluding extreme values from the existing data sets. Then the values calculated during the field studies, the literature values and HWGF values under HWDS were compared and these results used to determine the waste generation factor range as

Table 1
Waste list of injection moulding plant and HWGFs (kg t^{-1}).

Waste code	Definition of waste	A/M[a]	2009 HWDS		2010 HWDS		Plant 1		Literature		HWGF	
			Min	Max	Min	Max	Termo	Duro	Min	Max	Min	Max
16	Wastes not otherwise specified in the list											
1605	Gases in Pressure Containers and Discarded Chemicals											
160507	Discarded inorganic chemicals consisting of or containing dangerous substances	M	0.0114				22.2	7.4			0.011	22.2

[a] A: Absolute hazardous; M: Mirror entries.

Table 2
Waste list of extrusion moulding plant and HWGFs (kg t^{-1}).

Waste code	Definition of waste	A/M[a]	2009 HWDS		2010 HWDS		Plant 2	Plant 3	Literature		HWGF	
			Min	Max	Min	Max			Min	Max	Min	Max
07	Wastes from organic chemical processes											
0702	Wastes from the MFSU of plastics, synthetic rubber and man-made fibres											
070203	Organic halogenated solvents, washing liquids and mother liquors	A			0.7		10.26		0.2	40	0.2	40
070208	Other still bottoms and reaction residues	A	0.03	0.42	0.12	0.7		0.7	0.1	100	0.03	100

[a] A: Absolute hazardous; M: Mirror entries.

Table 3
Waste list of blow moulding process and HWGFs (kg t^{-1}).

Waste code	Definition of waste	A/M[a]	2009 HWDS		2010 HWDS		Plant 1	Plant 2	Plant 3	Literature		HWGF	
			Min	Max	Min	Max				Min	Max	Min	Max
12	Wastes from shaping and physical and mechanical surface treatment of metals and plastics												
1201	Wastes from shaping and physical and mechanical surface treatment of metals and plastics												
120120	Spent grinding bodies and grinding materials containing dangerous substances	M	0.0037	1.06	0.03	11.5						0.0037	11.5

[a] A: Absolute hazardous; M: Mirror entries.

Table 4
Waste list of dyeing sub-process and HWGFs (kg t^{-1}).

Waste code	Definition of waste	A/M[a]	2009 HWDS		2010 HWDS		Plant 1		Plant 2	Plant 3	Literature		HWGF	
			Min	Max	Min	Max	Termo	Duro			Min	Max	Min	Max
08	Wastes from the manufacture, formulation, supply and use (MFSU) of coatings (paints, varnishes and vitreous enamels), adhesives, sealants and printing inks													
0801	Wastes from MFSU and removal of paint and varnish													
080111	Waste paint and varnish containing organic solvents or other dangerous substances	M	0.0009		0.007	2.9	22.45	7.46					0.0009	22.45
080113	Sludges from paint or varnish containing organic solvents or other dangerous substances	M	0.0018	8.355	0.7	40							0.0018	40
080115	Aqueous sludges containing paint or varnish containing organic solvents or other dangerous substances	M												
080117	Wastes from paint or varnish removal containing organic solvents or other dangerous substances	M	0.25		0.01	0.1							0.01	0.25
080119	Aqueous suspensions containing paint or varnish containing organic solvents or other dangerous substances	M												

[a] A: Absolute hazardous; M: Mirror entries.

Table 5
List of non-process wastes generated by plastic product manufacturing and HWGFs (kg t^{-1}).

Waste code	Definition of waste	A/M[a]	2009 HWDS		2010 HWDS		Plant 1		Plant 2	Plant 3	Literature		HWGF	
			Min	Max	Min	Max	Termo	Duro			Min	Max	Min	Max
13	**Oil wastes and wastes of liquid fuels (except edible oils, and those in chapters 05, 12 and 19)**													
1301	*Waste hydraulic oils*													
130110	Mineral-based non-chlorinated hydraulic oils	A	0.00058	6.17	0.008	100							0.00058	100
130113	Other hydraulic oils	A	0.0022	16.67	0.008	619	22.5	7.48					0.002	619
1302	*Waste engine, gear and lubricating oils*													
130204	Mineral-based chlorinated engine, gear and lubricating oils	A			0.002								0.002	
130205	Mineral-based non-chlorinated engine, gear and lubricating oils	A	0.004	6.17	0.02	8							0.004	8
130208	Other engine, gear and lubricating oils	A	0.005	4.28	0.01	29			0.19				0.005	29
1303	*Waste insulating and heat transmission oils*													
130301	Insulating or heat transmission oils containing PCBs	A												
130307	Mineral-based non-chlorinated insulating and heat transmission oils	A	0.028	0.162		0.01							0.01	0.162
130310	Other insulating and heat transmission oils	A					1.05	0.35					0.35	1.05
1305	*Oil/water separator contents*													
130502	Sludges from oil/water separators	A												
130506	Oil from oil/water separators	A	0.193		0.02	4.93							0.02	4.93
130507	Oily water from oil/water separators	A	0.0011	0.058		178							0.001	178
130508	Mixtures of wastes from grit chambers and oil/water separators	A												
1307	*Wastes of liquid fuels*													
130703	Other fuels (including mixtures)	A												
15	**Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified**													
1501	*Packaging (including separately collected municipal packaging waste)*													
150110	Packaging containing residues of or contaminated by dangerous substances	M	0.00007	7.835			12.27	4.08	1.96				0.00007	12.27
150111	Metallic packaging containing a dangerous solid porous matrix (for example asbestos), including empty pressure containers	M	0.00002	0.00008	1.49	0.03							0.00002	1.49
1502	*Absorbents, filter materials, wiping cloths and protective clothing*													
150202	Absorbents, filter materials (including oil filters not otherwise specified), wiping cloths, protective clothing contaminated by dangerous substances	M	0.000007	11.82			25.5	8.48		0.6			0.000007	25.5
16	**Wastes not otherwise specified in the list**													
1601	*End-of-life vehicles from different means of transport (including off-road machinery) and wastes from dismantling of end-of-life vehicles and vehicle maintenance (except 13, 14, 16 06 and 16 08)*													
160107	Oil filters	A	0.032		3.8	0.005	0.9	0.3					0.005	0.9
1602	*Wastes from electrical and electronic equipment*													
160209	Transformers and capacitors containing PCBs	M												

160213	Discarded equipment containing hazardous components (2) other than those mentioned in 160209 to 16 02 12	M	0.00015	0.002	0.00014	0.01			0.00014	0.002
160215	Hazardous components removed from discarded equipment	A			0.02	0.06	7.8	2.16	0.02	7.8
1606	*Batteries and accumulators*									
160601	Lead batteries	A	0.0248	0.37	0.005	0.2	27.4	9.1	0.005	27.4
160602	Ni–Cd batteries	A	0.00011	0.01	0.001	0.004			0.0001	0.01
160603	Mercury-containing batteries	A								
160606	Separately collected electrolyte from batteries and accumulators	A	0.346			0.001			0.001	0.346
17	**Construction and demolition wastes (including excavated soil from contaminated sites)**									
1704	*Metals (including their alloys)*									
170410	Cables containing oil, coal tar and other dangerous substances	M	0.00094						0.00094	
1705	*Soil (including excavated soil from contaminated sites), stones and dredging spoil*									
170503	Soil and stones containing dangerous substances	M								
1706	*Insulation materials and asbestos-containing construction materials*									
170601	Insulation materials containing asbestos	M								
18	**Wastes from human or animal health care and/or related research (except kitchen and restaurant wastes not arising from immediate health care)**									
1801	*Wastes from natal care, treatment or prevention of disease in humans*									
180103	Wastes whose collection and disposal is subject to special requirements in order to prevent infection	A			0.003				0.003	
20	**Municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions**									
2001	*Separately collected fractions (except 15 01)*									
200121	Fluorescent tubes and other mercury-containing waste	A	0.000014	0.0216	0.0001	9	1.4	0.5	0.000014	9
200126	Oil and fat other than those mentioned in 20 01 25	A			0.01	0.05			0.01	0.05
200127	Paint, inks, adhesives and resins containing dangerous substances	M	0.0553	5.35	0.95	1.18			0.0553	5.35
200133	Batteries and accumulators included in 16 06 01. 16 06 02 or 16 06 03 and unsorted batteries and accumulators containing these batteries	A	0.0217	0.51					0.0217	0.51
200135	Discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components	M	0.0001	0.0108	0.03	0.06			0.0001	0.06

[a] A: Absolute hazardous; M: Mirror entries.

'kg t^{-1}'. However, since no data is available from literature, field study or HWDS for some wastes, it was not possible to give the HWGF value. Hazardous waste lists of plastic product manufacturing conducted in this study are classified as process, sub-process and non-process and given below.

According to the process;

- Injection Moulding (Table 1), Extrusion Moulding (Table 2) and Blow Moulding (Table 3)

According to sub-process;

- Dyeing (Table 4)

According to non-process;

- Non-process (Table 1)

In the manufacture of plastic products, code no. 07, 12 and 16 are listed in the process waste category in Tables 1–3.

Dyeing processes are used in industry as a sub-process. Therefore, code no. 08 as sub-process waste is shown in Table 4. The list of non-process wastes in Table 5 includes oil wastes, packaging waste, discarded equipment, batteries and accumulators, insulation materials and medical wastes.

As it can be seen from these tables, the HWGF may differ when comparing the values with literature studies, HWDS statements and field studies. As an example, for 'other still bottoms and reaction residues' under code no 070208, the values was found to vary from 0.03 kg t^{-1} (min) to 0.42 kg t^{-1} (max) from HWDS in 2009; 0.12 kg t^{-1} (min) and 0.7 kg t^{-1} (max) in HWDS in 2010. It is seen the value was 0.1 kg t^{-1} (min) and 100 kg t^{-1} (max) for this waste code in literature. We also found this value 0.7 kg t^{-1} for our field studies. So we could determine the HWGF value range from this data as 0.03 and 100 kg t^{-1} respectively for min and max HWGFs.

4. Conclusions

This paper presents the results obtained from the studies conducted in the plastic product manufacturing industries within the scope of the project titled "Hazardous Waste Management in Compliance with European Union Environmental Regulations in Turkey". The project was aimed to develop HWGF for the control of hazardous waste generation.

As a result, in the manufacture of plastic products, code no. 07, 12 and 16 are listed in the process waste category. Code no. 08 as sub-process waste was also listed. Oil wastes, packaging waste, discarded equipment, batteries and accumulators, insulation materials and medical wastes could be listed non-process wastes.

The HWGF values evaluated can be helpful to determine the estimated quantities of hazardous wastes generated by plastic product manufacturing industry by means of manufacturing capacity information of the industry. With this hazardous waste lists, waste generators in Turkey can easily classify their wastes in correct waste types and quantities to HWDS with the HWGF values.

It is clear from the result of this study that there only needs two basic data for the identification of hazardous waste from an industry. The first one is HWGF and the second one is capacity information. This study shows that hazardous waste production can be determined with the use of HWGFs. If the generation factors and capacity information are available, this method easily provides updated and detailed results.

It is believed that the results of this study are significant for the improvement of the hazardous waste management system in Turkey and useful to the decision makers, especially in the ministerial level.

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