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RESEARCH ARTICLE

Hazardous Wastes and Waste Generation Factors Originating from Battery and Accumulator Manufacturing Sector in Turkey

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Abstract:

Background:

Accurate and realistic data regarding hazardous waste generation is required to make improvements in the effective management of hazardous wastes. Battery and accumulator manufacturing industry is one of the priority industries which was investigated in this study under the project named "Hazardous Waste Management in Compliance with European Union Environmental Regulations in Turkey". The project investigated a number of different industries for the development of an internet-based system named as "The Hazardous Waste Declaration System" in order to meet the requirements of Turkey for hazardous waste management.

Objective:

In this paper, hazardous waste generation factors were asserted by means of the type and quantity of the hazardous waste originated from the battery and accumulator manufacturing sectors.

Method:

For this purpose, field studies were conducted in an industrial plant operating in the sector, in order to determine all inputs and outputs of the current manufacturing process utilized. Concurrently, hazardous waste generation declarations made by the industries in the years 2009 and 2010 to the Hazardous Waste Declaration System were evaluated and a range of hazardous waste generation factors were created using the possible minimum and maximum quantities for each waste and the results were compared with the data given in the literature.

Results:

This paper presents the waste lists and the hazardous waste generation factors for the battery and accumulator manufacturing sectors.

Conclusion:

It is believed that the study will provide invaluable information for other battery and accumulator manufacturing industries from the point of types and quantities and the management of hazardous wastes generated.

Keywords: Hazardous waste, Waste generation factor, Battery, Accumulator, Manufacturing Sectors, Waste Methodology.

1. INTRODUCTION

One of the most important stages of the management of hazardous wastes is to acquire accurate information on the amounts of different types of hazardous wastes generated. The lack of sufficient data on hazardous waste results in

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failure in the monitoring and control mechanism. Moreover, the acquired data on hazardous waste quantities enable the industrialists and the decision makers to determine waste prevention and minimization options for the industry. Therefore, in order to constitute the most efficient management system for hazardous wastes in Turkey, the current quality and quantity of the manufactured hazardous wastes should be known. Hazardous waste generation quantities per unit manufacturer (Hazardous Waste Generation Factor, HWGF) for leading industries can be determined by - geographical and sectoral distribution of the types and quantities of hazardous wastes - manufactured in Turkey. The waste generation factors are necessary for waste inventories and can be measured, calculated or estimated in terms of waste generated per worker per year or waste generated per product (production unit) per year [1]. Moreover, waste prevention and minimization actions can be established for the industry by the data obtained from the hazardous waste quantity determined by the number of products or the amount of raw material used.

In the literature, hazardous waste inventory and management studies in different countries have been reported by many researchers. Salihoglu reported earlier that there is no reliable information on hazardous waste generation in Turkey [2]. Hazardous waste generation information is required to ensure appropriate planning, implementation, and monitoring of any waste management system. It was stated that theoretical inventories can be valuable assets in supporting regulating agencies in developing countries for the implementation of hazardous waste management systems [3]. However, in developing countries, administrative managers have some difficulties in getting data directly from the producers. Therefore, there is a need to establish theoretical hazardous waste inventories using the Waste Generation Factors (WGFs) [3]. In another study, waste management complexity, necessity of reliable data, data estimations and influencing factors for waste generation were investigated and possible solutions were put forth [4]. There is a need for a comprehensive study on hazardous waste indicators based on sector-specific features to estimate hazardous waste production rates for different industrial sectors. For this purpose, in the study, sector-specific indicators were tested on three hazardous waste generating sectors namely the petroleum refineries, dry cleaners, and public hospitals in - Haifa Metropolis to develop a method for estimating the amounts of waste [5]. Waste Generation Rates (WGRs) were also investigated by conducting on-site waste sorting and weighing in four on-going construction projects in Shenzhen city of South China. The results showed that WGRs ranged from 3.275 to 8.791 kg/m^2 [6]. Another waste methodology was published and tested for estimating the field scale total construction waste generation rate to be used in a generalized construction waste management plan at a city/regional/country level [7]. Hazardous waste generation for Turkish pesticide manufacturing industry was investigated by Babuna *et al.* [8]. The obtained results showed that the hazardous waste generation values ranged from 10 to 56 kg per tonne of the produced active ingredient used in the relative industry. Medical hazardous waste generation rates were calculated as kg/bed/day, with 132 health-care facilities in Greece [9]. Similarly, the hazardous medical waste generation rates of four large hospitals in Korea were reported that varied from 0.14 to 0.49 kg/bed/day [10]. On the other hand, Eker and Bilgili reported that medical waste generation rates were equal to 2.11±3.83 kg/bed/day in Turkey [11]. Household hazardous waste was characterized to determine the rate of the household hazardous waste generation which was found to be in the range of 6.16 (0.16–31.74, 95% CI) g/person/day [12].

According to values given in the literature, it can be seen that there is a need to describe and calculate HWGF in order to find reliable solutions to problems and efficient management strategies. Therefore, to meet these requirements, the project entitled "Hazardous Waste Management in Compliance with European Union Environmental Regulations in Turkey" was carried out by the support of TUBITAK on behalf of the Ministry of Environment and Urban Planning (MEUP) in Turkey. The long-term goal of this study is to contribute to the management of hazardous wastes in ways that are compatible with hazardous waste regulations of Turkey, developed in accordance with the EU harmonization requirements. This goal will be accomplished by generating fundamental information providing the most efficient and cost-effective hazardous waste management strategies for Turkey. Regulation on Control of Hazardous Waste (RCHW) [13] establishes a framework for hazardous waste management and follows the general rules laid down in the Council Directive on Hazardous Waste. The waste codes in RCHW are fully transposed from European Waste Catalogue [14].

This article involves detailed studies conducted for the determination of types and quantities of the hazardous wastes obtained from battery and accumulator manufacturing industry which is one of the biggest industries in Turkey. Within this scope, for this purpose, field studies were conducted in an industrial plant in order to determine all inputs and outputs of the current manufacturing process utilized. Hazardous wastes generated by the main and sub-manufacturing processes and other activities including the process phases generated and their qualities and quantities were all determined. Through these data, the hazardous waste list and HWGFs based on the data obtained from field studies were determined for the industry. Declarations of the hazardous waste manufacturing quantity made by the

organizations for this industry to the Hazardous Waste Declaration System (HWDS) and the data for this industry given in the literature were evaluated and the value range of HWGF was formed by assessing possible minimum and maximum quantities for each waste.

2. METHODOLOGY

As a first step, for the classification of economic activities of waste generators, NACE Rev.2 (Statistical Classification of Economic Activities for European Community) codes were used in HWDS. Depending on the industrial structure in a country or region, the amount and type of hazardous waste may vary. When describing the variations in hazardous waste generation, it is therefore, necessary to consider the economic activities. In the EU, the common classification for economic activity is carried out by means of NACE code (general industrial classification of economic activities within the European Communities). The amounts of hazardous waste generation are therefore associated with NACE codes as much as possible [15].

In this system, every waste generator has the chance to select its own NACE Rev. 2 code from the list integrated into the system. Hence, the waste generators could enter their annual production capacities to the improved system for each NACE Rev.2 code. As a result, all possible expected wastes for each NACE Rev.2 code can be obtained. Thus, the produced wastes can be selected from these lists and the waste amount for that year can be entered by the waste generators.

Consequently, waste generators will be able to classify their wastes easily and, in this way, it will be guaranteed to obtain accurate waste types. For the control of waste amounts declared in the system, it was aimed to develop waste generation factors specifically 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” can enable to control declared waste amounts in the system. Thus, declarations which are expected to increase each year can be monitored and controlled efficiently in terms of waste type and generation amount by the MEUP.

3. FIELD STUDIES

The current study was started by classifying companies according to the procedure given below:

NACE Rev2 economic activity code of the battery and accumulator manufacturing industry is “Class 27.20 - Manufacturing of batteries and accumulators”, sub-class of manufacture of electrical equipment included in the section of the manufacturing industry (C.27) [16].

Field studies were conducted in a plant having a high production capacity. The on-site field studies were carried out at certain periods of time. The manufacturing processes of the plants were examined, and data related to the input and output quantities were taken for the processes examined. The process-based waste generation factors were tried to be calculated according to the information and observations achieved. Starter series batteries are designed and developed for automotive and Light Commercial Vehicles (LCV) in the plant [17] These batteries implement the start-up movement of the engine and provide power to all electric devices within the vehicle. They supply a high current power within a short time frame. For industrial applications [18], stationary and traction batteries with varied physical and internal structure specifications are manufactured in the plant. Stationary batteries are developed for use in a fixed single location. Their design and plate structure maintain current and power for a relatively long time frame.

Traction batteries are another type of industrial batteries, sharing a similar working principle as starter batteries. They are built to provide long-term power to electric vehicles in difficult operating conditions. These high-power batteries also come in Air-Matic Circulation models using tubular positive plates (PzS) featuring a rapid recharge capability.

Studies were conducted for the hazardous wastes in addition to the examination of the processes applied in the plant. The manufacturing data were examined with regard to hazardous wastes. The waste generation values determined were divided into the generation value of that year and “kg waste/ pcs accumulator” unit and, afterwards, waste generation factors were calculated. The list of waste and waste generation factors obtained from field studies was also utilized by the declarations of HWDS for 2010 issued by the plant. However, the plant's declarations of HWDS have not been used directly but have been re-evaluated considering the possibility of coding errors.

4. RESULTS AND DISCUSSION

The list of the hazardous wastes and waste generation factors on the process basis was presented in this section for all studies.

Two major waste groups are classified for the battery and accumulator industry as potentially hazardous. These classes are as follows:

- Wastes from lead thermal metallurgy" under code no 1004
- Batteries and accumulators" under code no 1606

"Slags from primary and secondary production" coded as 100401 and "dross and skimmings from primary and secondary production" coded as 100402 included under "Wastes from lead thermal metallurgy" coded as 1004 are the wastes observed in field studies conducted for manufacturing batteries and accumulators.

"Lead batteries" coded as 160601 included under "Batteries and accumulators" coded as 1606 are also the wastes observed in field studies. "Electrical and Electronic Equipment Wastes" under the code of 1606 are hazardous wastes regardless of their concentration. The lead batteries emerge between the assembly and charging process are not produced properly.

Additionally, discarded chemicals, oil wastes, packaging wastes, oil waste filters, insulation materials, medical wastes and treatment sludges were observed as non-process wastes. Plant manufacturing data were examined to determine the quantities of hazardous wastes in the plants. The waste generation values divided into the generation value of that year and "kg waste/ pcs accumulator (kg/pcs accu)" unit and the waste generation factors were calculated.

The HWGFs were found by means of reviewing literature, field studies and HWDS. As a result, the obtained list of the process, sub-process and non-process wastes expected from the manufacturing batteries and accumulators and the HWGFs were presented in Table **1**. During the determination of the HWGF values, the average values were calculated from declarations of HWDS. The values and the literature values were compared to each other and an average waste generation factor was determined as 'kg/pcs'. However, since no data could be supplied from any literature or field study or HWDS for some wastes, it was not possible to give the HWGF value. The value declared in the HWDS with the code of 100401 is between 0.36 kg/pcs accu and 0.7 kg/pcs accu. The values found in the field studies were determined to be 0.3 kg/pcs, lower than the battery HWDS values. As seen in Table **1**, the hazardous waste generation factor range of the waste coded as 100401 was determined to be between 0.3 and 0.7 kg/pcs accu.

As a consequence of the field studies, the generation factor of waste coded as 100402 was determined as 0.03 kg/pcs accu. It was found as 0,042 kg/pcs accu in HWDS. The hazardous waste generation factor range of 100402 coded waste was selected as 0.03- 0.04 kg/pcs accu as seen in (Table **1**).

The waste generation factor of 160601 coded waste was found as 1.68 kg/pcs accu in the field study and 1.3-2.1 kg/pcs accu in HWDS. The number of 1.68 in field studies is in the range of 1.3 to 2.1 in HWDS. The waste generation factor range of the waste coded as 160601 was selected from 1.3to 2.1 kg/pcs accu as seen in (Table **1**).

Table 1. Waste list of Battery and Accumulator Manufacturing Plant and HWGFs.

	Waste Code	Definition of Waste	HWGF (Kg/Pcs Accu)
Process Wastes	10	Wastes from thermal processes	
	1004	Wastes from lead thermal metallurgy	
	100401	Slags from primary and secondary production	0.3-0.7
	100402	Dross and skimmings from primary and secondary production	0.03-0.04
	16	Wastes not otherwise specified in the list	
	1606	Batteries and accumulators	
	160601	Lead batteries	1.3-2.1
Sub-Process Wastes	16	Wastes not otherwise specified in the list	
	1605	Gases in pressure contaiiners and discarded chemicals	
	160507	Discarded inorganic chemicals consisting of or containing dangerous substances	

(Table 1) contd.....

	Waste Code	Definition of Waste	HWGF (Kg/Pcs Accu)
Non-Process Wastes	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	
	130113	Other hydraulic oils	0.0002
	1302	Waste engine. Gear and lubricating oils	
	130204	Mineral-based chlorinated engine. Gear and lubricating oils	
	130205	Mineral-based non-chlorinated engine. Gear and lubricating oils	
	130208	Another engine. Gear and lubricating oils	
	1303	Waste insulating and heat transmission oils	
	130301	Insulating or heat transmission oils containing pcbs	
	130307	Mineral-based non-chlorinated insulating and heat transmission oils	
	130310	Other insulating and heat transmission oils	
	1305	Oil/water separator contents	
	130502	Sludges from oil/water separators	
	130506	Oil from oil/water separators	0.001
	130507	Oily water from oil/water separators	
	130508	Mixtures of wastes from grit chambers and oil/water separators	
	1307	Wastes of liquid fuels	
	130703	Other fuels (including mixtures)	
	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	0.0005-0.0006
	150111	Metallic packaging containing a dangerous solid porous matrix (for example asbestos). Including empty pressure containers	0.032
	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	
	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	
	1602	Wastes from electrical and electronic equipment	
	160209	Transformers and capacitors containing PCBS	
	160213	Discarded equipment containing hazardous components (2) other than those mentioned in 16 02 09 to 16 02 12	0.0002
	160215	Hazardous components removed from discarded equipment	
	1606	Batteries and accumulators	
	160602	Ni-Cd batteries	0.000004
	160603	Mercury-containing batteries	
	160606	Separately collected electrolyte from batteries and accumulators	
	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	
	1705	Soil (including excavated soil from contaminated sites). Stones and dredging spoil	
	170503	Soil and stones containing dangerous substances	
	1706	Insulation materials and asbestos-containing construction materials	
	170601	Insulation materials containing asbestos	
	18	WASTES FROM HUMAN OR ANIMAL HEALTH CARE AND/OR RELATED RESEARCH (except kitchen and restaurant wastes not arising from immediate health care)	
	18 01	Wastes from natal care. Diagnosis. Treatment or prevention of disease in humans	
	180103	Wastes whose collection and disposal is subject to special requirements in order to prevent infection	
	19	Wastes from waste management facilities, off-site wastewater treatment plants and the preparation of water intended for human consumption and water for industrial use	
	1908	Wastes from waste water treatment plants not otherwise specified	
	190813	Sludges containing dangerous substances from other treatment of industrial waste water	0.00003
	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	0.000004
	200126	Oil and fat other than those mentioned in 20 01 25	0.0001
	200127	Paint. Inks. Adhesives and resins containing dangerous substances	
	200133	Batteries and accumulators included in 16 06 01. 16 06 02 or 16 06 03 and unsorted batteries and accumulators containing these batteries	
	200135	Discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components	0.000002

CONCLUSION

This paper presents the results obtained from the battery and accumulator manufacturing industry within the scope of the project entitled “Hazardous Waste Management in Compliance with European Union Environmental Regulations in Turkey”. The study aimed to develop efficient control mechanisms for the control of hazardous waste generation. Along with the waste lists determined in the project studies, the HWGF value ranges were determined through literature review for this industry, declarations of HWDS for years of 2009 and 2010. In the manufacturing of battery and accumulator, the code number of 10 and 16 are listed in the process waste category. During the manufacturing process “slags from primary and secondary production” coded as 100401, “dross and skimmings from primary and secondary production” coded as 100402 and “lead batteries” coded as 160601 were detected to be the most important wastes. Discarded chemicals, oil wastes, packaging wastes, oil waste filters, insulation materials, medical wastes and treatment sludges were determined as the non-process wastes observed in field studies. It is believed that the results of this study are significant for the improvement of the hazardous waste management system and it will provide valuable information to the decision makers, especially at the national level. The HWGF values can also be helpful to determine the estimated quantities of hazardous wastes generated by battery and accumulator manufacturing industry by means of manufacturing capacity information of the industry. HWGF values in the process waste category were found to be in the range between 0.03 and 2.1 kg/pcs accu.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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