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Waste Management Planning in Amirkabir Petrochemical Complex

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Abstract

The Amirkabir petrochemical complex (APC) is located in the south of Iran, on the northern coastline of the Persian Gulf. It has five different units which generate various waste estimated at 3115.98 ton/year. The objective of this study was to focus on the management of the processing wastes for minimizing the adverse environmental impacts. In order to properly manage and control waste generation at APC, the quantity, type, and composition of industrial wastes must be known. Therefore, questionnaires were used to collect data. Classification of industrial wastes was carried out based on a comparative analysis and synthesis of studies pertaining to petrochemical waste management. Whereby unique coding system is essential for integrated management of industrial waste, a thirteen-digit code was assigned for each waste. The main types of waste were 9.58% catalysts, 7.62% metallic materials, 35.77% plastic barrel, 12.66% coke, 4.47 % wood, 4.15% oil, 0.028 % glass, 6.7% cooling tower packing and 18.83% other material. Physical properties analysis of the wastes showed that 11.81% of these residues were liquid and 88.19% were solids. Serious problems were encountered in the present management of these wastes. The waste management at APC was quite complicated because of the diversity of wastes and their hazardous characteristics (88.19% hazardous waste). In some cases, recycling/reuse of waste was the best option, but incineration and disposal are also essential choices.

Keywords: Amirkabir petrochemical complex, Petrochemical industry, Hazardous waste, Waste management, Waste coding.

Introduction

Over the past years, many parts of the world have witnessed a remarkable evolution in the management of solid waste management, from open dumping on the land and indiscriminate burning, to integrated systems incorporating waste processing, recycling, and treatment. This progress made public’s growing awareness of the need to protect human health and the environment and the importance of resource and energy conservation. Governments, businesses, and individuals now recognize, and in many cases embrace, the adoption of sustainable practices in many aspects of daily life, including the management of solid waste.

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Improper industrial and municipal waste management can lead to many forms of contamination, such as groundwater contamination, air quality deterioration, and greenhouse gas emissions (Usapein and Chavalparit 2014). Industrial waste is the waste produced by industrial activity which includes conventional wastes and hazardous waste. Currently, industrial activities are the main sources of world’s hazardous waste production (Al-Qaydi 2006). Today, most manufacturing plants are in need of detailed analysis of their waste management system at all stages of production. Those who have already studied waste streams within the company and who have identified opportunities for recovery and resource saving usually find that there are large economic as well as environmental benefits to be gained when appropriate waste management is implemented (McDougall, White et al. 2008).

Petrochemical industries, similar to other waste generating sources, are associated with numerous waste-related environmental problems. However, petrochemical wastes are generally associated with more hazardous constituents, and as such have a higher public health and environmental risk potentials. Industries generate complex wastes, a complexity not only due to the quantity of wastes but also to their composition (Wei & Huang, 2001). The term industrial waste refers to all wastes produced by industrial operations or derived from manufacturing processes (Abduli, 1996). Industries have traditionally managed their waste products by discharging them into the environment without previous treatment. This practice resulted in an increase of pollution and produced an adverse environmental impact. The requirement for environmental quality resulted in a change of the whole concept of pollution control (Vigneswaran,et.al., 1999). Industrial Waste Management history returns to approval of Resource Conservation Recovery Act in United States in 1976. The first laws and regulations pertaining to hazardous waste management have been implemented in member countries of the Common Market in 1980, Europe (Karami, Farzadkia et al. 2011). In recent years, industrial waste management is interested by many researchers. Hogland and Stenis (2000) found a method of organizing a waste management system and obtained an overview of the whole system. The method proposed emphasizes the optimization of waste management with regard to energy, economy and environmental impact in separate evaluations. The case study presented illustrates how the method was applied to a paper-mill in Sweden. The results showed that the methodology was also suitable as a basis for the development of more specific methodologies for the analysis of waste handling systems applicable to other branches of industry. In a study by Su et al., the properties of waste catalysts was analyzed and the feasibility of reusing them to substitute part of the cement required in mortar preparation was found (Su, Fang et al. 2000). The waste catalysts were mainly composed from SiO_2 and Al_2O_3 which could substitute up to 15% of the cement content in mortar without sacrificing the quality of concrete. The biodegradation of petrochemical wastes were reviewed by Singh et al. (2017). The environmental assessment of land filling of petrochemical wastes was also found (Musin, Kurlyanov et al. 2016). Results showed that the landfill negatively impacts groundwater. Ko et al. (2016) assessed unsustainable disposal of pyrolysis fuel oil (PFO) as a petrochemical waste. They used PFO as an anode material for lithium-ion batteries. Their study revealed that this waste exhibited a much higher reversible capacity than that of commercial soft carbon and an extremly stable recoverability.

Petrochemical industries are among the most important and critical industries in Iran. Petroleum refineries and petrochemical industries generate a series of different kinds of hazardous wastes. The primary hazardous wastes associated with petrochemical industry can be classified into three main categories: process wastes; equipment cleaning wastes; and wastewater treatment wastes.

There are few examples of petrochemical industries in Iran that manage their wastes. For example, Imam Port (2000) and Tabriz petrochemical complexes (2004) use a method of organizing an industrial waste management system which is characterized by recovery, reuse, land filling and other waste management practices.

The main objective of this study is to focus on management of waste produced at petrochemical complexes located at the petrochemical especial economic zone and to find challenges as well as proposing an integrated waste management framework for petrochemical industry.

Material and Methods

Case study and Data collection

A There are sixteen petrochemical complexes in the petrochemical especial economic zone (PEEZ). The zone is located on the shore of the Persian Gulf at Mahshahr port. Amirkabir petrochemical complex (APC) is one of these complexes that occupies 55 hectares of land. Figure 1 shows the position of APC at Mahshahr port among the other petrochemical complexes.

Figure 1: location of Amirkabir petrochemical zone in especial economic petrochemical zone

APC is established in 1998 and has been in operation since 2004. Main products of the complex include high-density poly ethylene, ethylene, 1-Butene, propylene, 1, 3-Butadiene, linear low-density poly ethylene and crude fuel oil. A general view of generation units with raw material and products is illustrated in Fig.2. As it is seen in Fig.2, there are five units in APC including linear low-density poly ethylene unit (LDPE), high-density poly ethylene (HDPE) unit, 1-butene unit, Butadiene unit, and olefin unit. Olefin is one of major products of petrochemical industries. The important process of producing olefin is thermal decomposition of hydrocarbons. The olefin unit provides the feed for LDPE and HDPE units. HDPE unit feeds with butane, hydrogen, and catalysts. After polymerization, the output products entered to centrifuges where powder and hexane separated. Then, hexane is refined for reusing purpose and the powder is dewatered and granulized by extruders. The reaction of producing LDPE occurs in high pressure. To begin the reaction, organic peroxides are added during multiple stages. In presence of ethylene, propen, and propylene and high pressure, polymerization begins and the powder is sent for granulation using extruders.

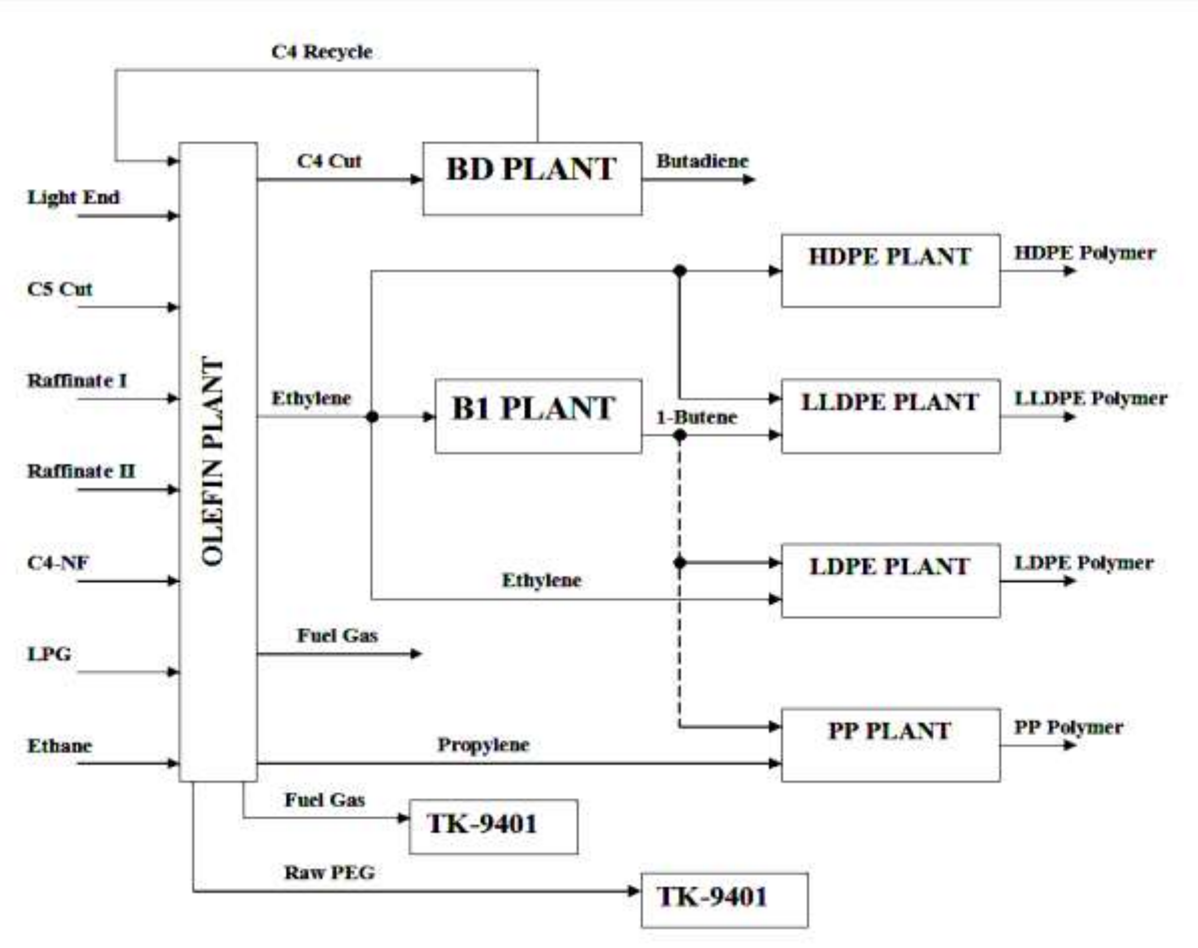

Figure 2: Brief process diagram of Amirkabir petrochemical complex

Currently, three different methods have been widely used to analyze the generation, type and composition of industrial waste (Monahan, 1990):

- An empirical approach using available industry information;
- A questionnaire survey;
- Use of control/monitoring data from a waste management system;
- Document of waste emission lists reported by designers.

International research give examples of using questionnaires to study the quantity and quality of industrial wastes, along with the management and control methods used (Abduli, 1996; Asadi, et al., 1996; El-Fadel, et al., 2001; Monahan, 1990; Nirich, et al., 2000). Based on previous studies carried out in other countries as well as Iran (Abduli, 2005), our research group, prepared a questionnaire regarding the functional elements and organizational structure of petrochemical waste management practices. It included information on the following items:

1- General information:
  1-1- Unit name;
  1-2- Raw materials and products;
  1-3- Waste type and its components.

2- Generated waste information:
  2-1- Volume or weight of waste according to design and actual value;
  2-2- Generation frequency;
  2-3- Type of waste containers used for on-site storage and their collection frequency.

3- Information about current waste management:
  3-1- Methods of waste collection;
  3-2- Present disposal methods;
  3-3- Disposal methods proposed by the plant designer for the waste which will generate in the future.

Reconnaissance surveys were carried out to locate the sources of waste generation and obtain preliminary data on different activities and operations as well as update data on their operational status. To obtain proper information, the questionnaires were given to the managers of environmental, processing, operating, repairing, municipal waste collection sections and laboratories and face to face interviews were conducted with the managers of discussed sections. The information was then compared with each other to assess the accuracy of the collected and finalized for the analysis.

Waste classification

The quantity and quality of petrochemical wastes usually depend on the characteristics of each unit process (Abduli, 1996). To make proper management decisions such as recovery, sale, incineration or landfilling, waste classification systems such as united nation environmental program (UNEP), Basel convention and Conservation and Recovery Act (RCRA) were evaluated, and the classification method which had the most compatibility was used. Meanwhile, classification methods were also updated according to local condition. In order to control waste management from cradle-to-grave, wastes were classified into ten major groups: 1) lab packs, 2) inorganic liquids, 3) organic liquids, 4) inorganic solids, 5) organic solids, 6) inorganic sludge, 7) organic sludge, 8) inorganic gas, 9) organic gas and 10) plant trash. A code was designated to each group that is called “form code”.

Waste coding

A unified coding system was necessary for all wastes generated at PPEZ petrochemical mills. On the other hand, waste generators should be easily perused routs of waste date from generation point to its final disposal. Therefore, system coding should be contained waste characterizations. Thirteen-digit codes were designed in this study consist of four words for waste generator’s name, three digits for waste stream number, three digits for code form, one word indicating waste source (industrial, agricultural, medical or non-industrial) and one word reefing to waste hazard part code. Individual code for each waste type is written on its label.

Results and Discussion

*Non-process waste*Industrial wastes are categorized in two groups including process and non-process wastes. Non-process wastes are produced by the sources and process excluding production processes. The petrochemical solid wastes are generated by various processes that support industrial operations, and as such their generation rates are related to their nature and are directly proportional to the extent of these processes. Plant offices, staff restaurant, laboratories, lop of trees or plants and other personnel-related activities; generate the non-process industrial solid waste (ISW). This waste type was collected and deposited by municipal council to disposal area located in Omidiyeh pathway. Medical wastes were separately handled and incinerated in Mahshahr medical incinerator. Fig.3 shows weight percents of municipal, agricultural and municipal wastes. It is noted that only 14.9% of wastes were non-process ISW and 85.1% of them was processed ISW.

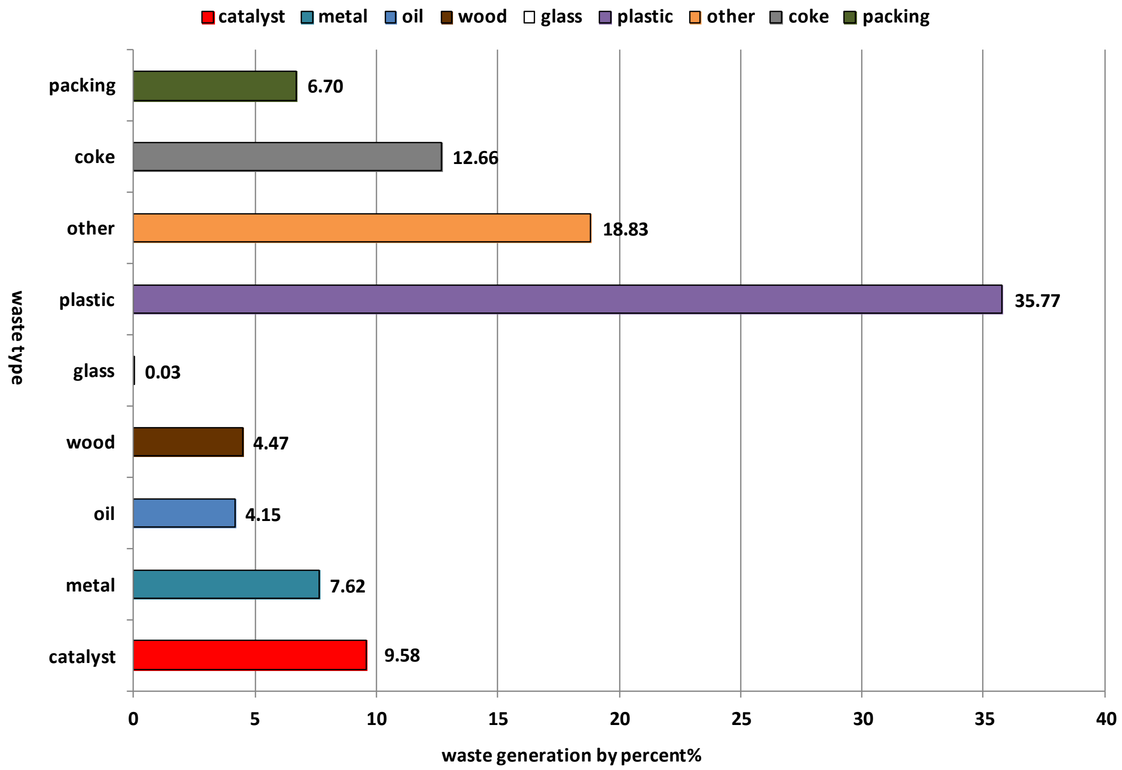

Figure 3: Composition generated waste in Amirkabir petrochemical complex

Process waste

After analyzing the process, solid wastes of APC, 68 source points of waste generations were detected. These generate 3115.98 tons solid waste annually. Table 1 illustrates a list of generated wastes at APC process. In the view of hazard characteristics, wastes divided into four hazard classes based on modified classification system: class H: wastes have hazardous characteristics under RCRA. Class 1: wastes have been polluted by toxic pollutant over a standard threshold (for example, water contaminated by ethylene glycol), class 2: wastes have not contained or been mixed with the waste of class H but have little hazard after disposal and class 3: inert wastes have no undesirable effect on the environment. Fig 5 shows generation rate of each class. As shown in Fig. 4, 88.19% of the generated solid wastes in this complex were hazardous, and 11.81% of them were a non-hazardous waste. Therefore, the hazardous waste such as catalysts and oil should be managed before disposal.

Table 1: Wastes generated at Amirkabir petrochemical complex

emission source*	waste type	liquid	solid	waste stream
1,2,3,4,5	waste oil	✓		22.3 ton/year
1	packing of cooling tower		✓	180 ton/5year
1	empty barrel		✓	12.78 ton/year
1	Perlite		✓	5 m3/5year
1	coke		✓	46 m3/year
1	molecular sieve		✓	70 ton/7year
1	spent catalyst		✓	22 m3/5year
1	spent catalyst		✓	4 m3/3year
1	activated carbon		✓	5.2 m3/5year
1,5	resin		✓	13 ton/5years
1	activated carbon and molecular sieve		✓	2.4 m3/10year
6	oil filters		✓	0.192 ton/year
6	metallic wastes		✓	23.48 ton/year
6	industrial coal		✓	0.005 ton/year
6	gasoline waste	✓		1 lit/day
6	tubes		✓	400 kg/year
2, 4,5, 8	Off specification products		✓	1054.9 ton/year
8	plastic bags		✓	90 kg/day
7	empty container of chemicals		✓	174 kg/year
7	laboratory sample	✓		1760 lit/6month
6	rock wool		✓	2 ton/year
6	Aluminum		✓	2.5 ton/year
5	stabilizer powder		✓	1300 kg/4month
5	wax		✓	1120 ton/year
5	catalytic sludge		✓	52 ton/year
5	hexane waste	✓		362 ton/year
4	spent catalyst	✓		40 ton/year
3	Normal methyl Pyridine	✓		24 ton/year
2	melt		✓	3.5 ton/month
8	wooden pallet		✓	24 ton/year
8	plastic pallet		✓	431 kg/day
7	glass		✓	0.15 ton/year
7	plastic		✓	0.024 ton/year
9	Food waste		✓	1.5 ton/day

* Olefin=1, Linear low density poly ethylene=2, butadiene=3, 1-Butene=4, High density poly ethylene=5, Repairing=6, Laboratory=7, Store=8, & restaurant=9.

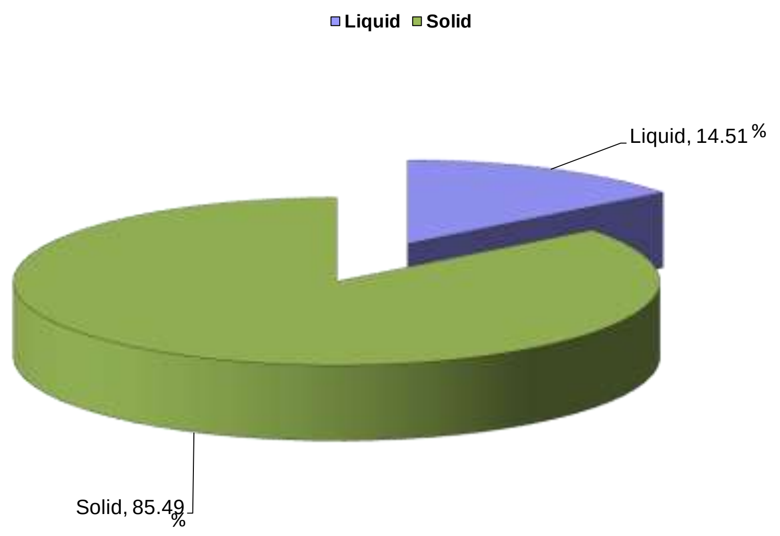

Figure 4: waste classification based on physical properties

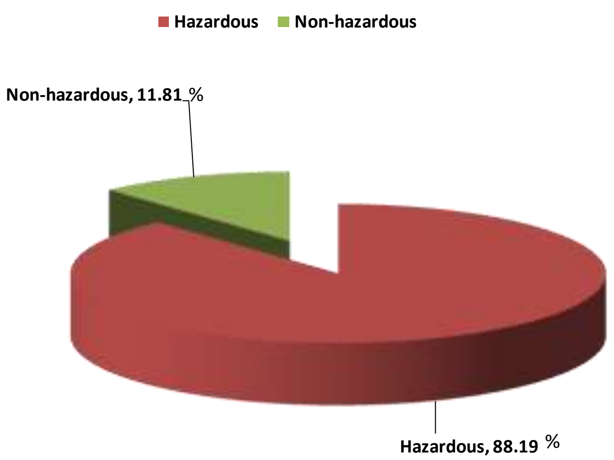

Figure 5: waste classification based on hazardous properties

Major waste types are shown in Fig.5. It was observed that the generated wastes at APC are consisted of 9.58% catalysts, 7.62% metallic materials, 35.77% plastic barrels, 12.66% coke, 4.47 % wood, 4.15% oil, 0.028 % glass, 6.7% cooling tower packing and 18.83% other wastes. It can be noted catalysts are the main part of the solid wastes. Physical properties analysis of generated wastes showed that 14.41% of these wastes were liquid and 85.49% of them were solid (Fig. 6).

Evaluation of recommended and present waste management

The data in Table 2 shows that some wastes aren't managed properly. Proper management is based on handling, processing and disposing of wastes without adverse environmental impacts. Therefore management of these wastes was necessary. Except for by-products which are sold, 35.51% of the total wastes are stored, and 11.92% are incinerated. Also, there are some wastes (11.94%) that generate in future. It has considered no particular management methods for such wastes. Analyzing the data shows many problems in present IWM as follows:

Temporary storage of waste especially hazardous ones at generation point had no standard condition.
No labeled containers have considered except for some hazardous wastes.
Handling method to salvage was improper.
Some hazardous wastes stored over 90 days.
Incompatible waste stored at the temporary storage place.
Temperature, isolation, light, etc. of HW storage place had no control.
Recoverable wastes such as catalytic sludge, catalyst, plastics were landfilled.
Qualities of wastes didn't measure, and composition of some waste wasn't apparent.
Non-process waste was been deposited off.

Table 2: Current situation of waste management in Amirkabir petrochemical complex

Recovery%	Landfill%	Store%	Incineration%	Sell%	not managed%
2.48	0	21.21	7.12	21.79	7.13

Integrated solid waste management involves using a combination of techniques and programs to manage a community's waste stream. To account for variations in waste streams between communities, planners can tailor integrated waste management systems to fit specific local needs. EPA suggests using the following hierarchy as a tool for setting goals and planning waste management activities (Fig.6).

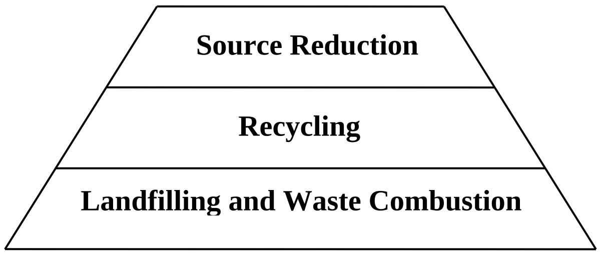

Figure 6: Integrated solid waste management hierarchy

As discussed above, most of the wastes which are generated in petrochemical industry have hazard potentials. The best management procedures are described in the following section. Many industries reuse directly or recycle waste materials for use as raw materials in their production processes. Both intra- and inter-industry reuse and recycling are practiced. In intra-industrial reuse and recycling, waste materials are collected from generation points and reused directly in industrial processes or recycled for eventual use within the same industry. It is noteworthy that, recovery of useful ISW materials for recovery and recycling takes place at practically all stages of industrial processes from loading of raw materials, to the packing of finished products. As shown in Table 3, 39.34% of wastes are recoverable and reusable, and 5.12% are ignitable. Recovery of wastes is economical and is one of the best waste management options. These technical ways can eliminate waste removal costs, decrease raw materials costs and produce extra income through selling out wastes to recovery centers. Waste hexane has the capability of recycling and reusing. Due to the presence of valuable metals and also toxic and hazardous metals, spent catalysts should be recovered. Metallic material, oil, spent resin and absorber have recovery potential too. Laboratory samples should just be incinerated because they have low volumes and high toxity. After perfuming solid waste management system, all wastes will be handled properly. Therefore adverse environmental impacts of wastes can be mitigated; occupied space by wastes can be removed and extra income can be obtained.

Table 3: anticipated results of APC solid waste management in the future

Recovery%	Landfill%	Store%	Incineration%	Sell%	not managed%
39.34	19.05	0	5.12	36.48	0

Conclusion

Questionnaires have been used as a tool to learn about the management of wastes in industrial areas, as well other types of wastes (Abduli, 1996; Asadi et al., 1996; El-Fadel, et al., 2001; Monahan, 1990). The use of questionnaires to obtain data regarding the production, characterization and management of industrial wastes should also be accompanied by other studies concerning the type of industrial activity in the area of research. This would avert certain problems associated with this method of data collection. The obtained information provided an approximation of the quantity of generated wastes, as well as their characteristics and composition. Nevertheless, the use of control/monitoring data from a waste management system (Monahan, 1990) is necessary in order to obtain more precise information. Except off quality products, catalyst, oil, absorber, resin and cooling tower packing are the most significant waste groups insomuch as the volume is concerned. These wastes were classified concerning physical and hazardous properties.

After evaluating present waste management system, system defects were found. Occupied waste space and their hazard potential were very high, and some wastes didn't consider any management method for them. According to the priority of waste management strategies, we chose the best management options. 39.33% of wastes can be recovered, 5.12% of them can be incinerated and 19.05% of them should be land filled. Proper waste management system helps us to mitigate adverse environmental impacts of wastes as well as its other benefits.

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