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Quality and Quantity of Wastes Generated in Marun Petrochemical Complex and Evacuating Recovery Potential

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ABSTRACT

Waste recycling is one of the favorable methods in waste management. Since huge amount of hazardous and non-hazardous wastes are produced in petrochemical industry, it is essential to characterize generated wastes and evaluate their recovery potential. Marun petrochemical complex (MPC) is located in Petrochemical Especial Economic Zone (PEEZ) on the northern coastline of the Persian Gulf. Waste management in MPC is quite complex due to diversity and their hazards to the environment and human health. In this study, different types of waste including processing and non-processing wastes were investigated. The recoverable wastes were estimated and effect of recycling on present waste management was assessed. Proper management of waste needs waste characterization including quantity, type, and composition. Therefore, questionnaires were used to collect data. During five units of production process, 6199 ton of solid, liquid, and hazardous wastes were generated in MPC annually. Classification of industrial establishments was made based on a comparative synthesis and analysis of recent nationwide surveys and studies pertaining to petrochemical waste management. Results showed that the major parts of waste were catalysts, metallic materials, plastic barrel, 3.78% paper, wood, oil and glass respectively. In the view of physical properties, 80.1% of wastes were solid and remain was liquid. Serious problems were observed in the present management of these wastes such as in-situ dumping of wastes and low recycling. It is estimated that about 5000 ton of waste had optional of recovery. Therefore, waste recycling was recommended in MPC among other techniques of waste management.

1. Introduction

Industrial development and rapid population growth resulted in increase of industrial waste generation (Abduli, 1996; Faboya, 1997). The term industrial waste refers to all wastes produced by industrial operations or derived from manufacturing processes (Faboya, 1997). Industries have traditionally managed their waste products by discharging them into the environment without treatment (Abduli, 1996). This resulted in an increase of pollution and produced a negative environmental impact (El-Fadel *et al*, 2001; Békaert *et al*, 2002). The careful disposal of industrial wastes means desired options for managing industrial waste to minimize the amount of waste generated by modifying the industrial process involved, transfer the waste to another industry that may use the waste, reprocess the waste to recover materials and energy, separate hazardous and nonhazardous materials, subject the waste to some process that will render the waste nonhazardous, and dispose of the waste in a sanitary landfill (Faboya, 1997; Pichtel, 2005, White *et al*., 2012).

Waste management infrastructure plays an important role in delivering sustainable development (Aoki & Cioffi, 1999; Costa *et al*., 2010). Rapid population growth in developing country like Iran has led to depletion of natural resources (Giusti, 2009). Wastes are potential resources and waste management with resource extraction is fundamental for effective waste management (Wei & Huang, 2001; Mbuligwe & Kaseva, 2006). Recycling valuable materials in industrial wastes is crucial to reduce adverse effect of waste disposal and prevent depletion of natural resources (Lambolez *et al*., 1994; El Haggar, 2010). Waste can be recovered to new products, raw materials, energy or nutrients (Mbuligwe & Kaseva, 2006, CRS, 2017). The conversion from wastes to resources can only be achieved through investment in waste management as this depends on coordinated actions to develop markets and maximize recovery of recyclable or reusable materials (Wei & Huang, 2001; Mbuligwe & Kaseva, 2006). Many industries have contributed to generation of new contaminants which are toxic and hazardous for the environment (Lambolez et al., 1994). Therefore, effective control and proper management of industrial waste for

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health, environment and resource management are of particular importance. In terms of quantity, the amount of industrial waste produced varies considerably depending on type of product, life of the equipment, production process and production rate. Therefore, it is essential to conducts for a particular industry (Giusti, 2009).

Petrochemical industry is one of the key industries in Iran. Mismanagement of wastes generated in petrochemical industries can produce environmental problems due to hazardous characteristics (McBee et al., 1987). Recycling is more preferable than landfilling where waste needed to be treated or neutralized due to high toxicity prior to disposal. A multi objective optimization model based on the goal programming approach was proposed to assist in the proper management of hazardous waste generated by the petrochemical industry (Alidi, 1996). The analytic hierarchy process, a decision-making approach, incorporating qualitative and quantitative aspects of a problem, was incorporated in the model to prioritize the conflicting goals usually encountered when addressing the waste management problems of the petrochemical industry.The results obtained show that the model was a viable tool and could be used to assist in making appropriate decisions regarding the management of petrochemical wastes. Wei (2003) presented the key components of the incineration system for the petrochemical wastes and analysis the characters and the adaptation of several types of the incinerators in common use . The Reuse of Petroleum and Petrochemical Waste in Cement Kilns studied by Gossman (1992). The results showed that the use of petrochemical wastes in cement kilns can have significant positive impact on product quality, operations and the environment with adequate specifications and quality control. Garret (1959) showed that tars, spent catalysts, and complexes as petrochemical waste were recoverable. In other study, ecological and practical aspects of the use of petrochemical waste in the production of refractory heat insulation material based on water glass was assessed (2011). It was established that petrochemical high-alumina waste should be used in the production of refractory heat insulation materials based on water glass. This promoted a considerable increase in the refractoriness of heat insulation materials.

The aim of this study was to assess the quality and quantity of wastes generated in a petrochemical complex and estimating recovery potential. We also examined the effect of waste recovery on the present waste management system in Marun petrochemical complex.

2. Method

2.1. Data collection

There are three general methods presently used to analyze the generation, type and composition of industrial waste (Monahan & Lu, 1990, Tourangeau & Smith, 1996):

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..

Present studies (Asadi *et al*., 1996; El-Fadel & Massoud, 2001; Delmonico *et al*., 2018; Siejka & Mika, 2017) used questionnaires to identify the quantity and type of industrial wastes generated, along with the management and control methods. According to the studies carried out in other countries as well as in Iran (Abduli et al., 2006), a questionnaire was prepared regarding the functional elements and organizational structure of petrochemical waste management practices. The questionnaire included information on the following items:

• General information including unit name, raw materials, products, waste type and its components.

• Waste information including volume or weight of waste according to design and actual value, generation frequency, type of waste containers used for on-site storage and their collection frequency.

• Information about present waste management including methods of waste collection, present disposal methods, 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 get preliminary data on different activities and operations as well as update data on their operational status. To obtain proper information, this questionnaire was given to the managers of environmental, processing, operating, repairing, municipal waste collection sections and laboratories and face to face interviews were done with managers. The similar information was then compared with each other to demonstrate accuracy of collected data because in some cases, quantity of same wastes was different. The final data were used for analyzing.

2.2. Case study

Marun Petrochemical Co. (MPC) is the second largest ethylene manufacturer in Iran. Marun is the first company in the country that extracted C2+ (ethane) from natural gas in an ethane recovery unit as an intermediary product. MPC was founded in 1999 and is located in Mahshahr Petrochemical Special Economic Zone in Khuzestan. Figure 1 shows the location of MPC at Mahshahr port among the other petrochemical complexes.

This company with the capacity of producing 1100000 tons of Ethylene, 200000 tons of polypropylene, 300000 tons of polyethylene, 300000 tons of polypropylene, and more than 443000 tons of Glycol is one of the greatest petrochemical companies in Iran and in the world.

MPC. Major products of the complex include high poly ethylene, ethylene, pyrolyze benzene, propylene, glycol ethylene and propane cuts. A general view of generation units with raw material and products is illustrated in Figure 2. As it is seen in Fig.2, there are five units in MPC that include olefin unit, high poly ethylene unit, poly propylene unit, EO/EG unit and utility unit.

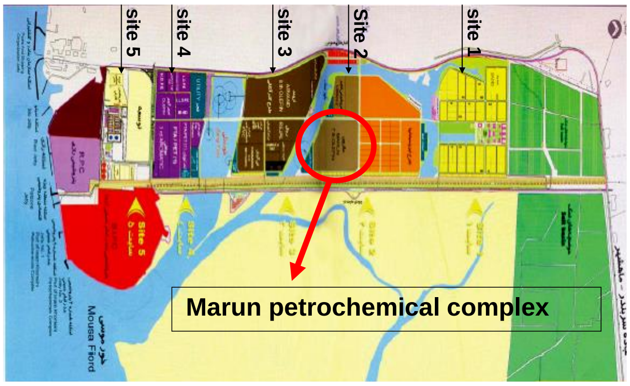

Figure 1. location of Marun petrochemical zone in especial economic petrochemical zone.

2.3. Waste classification method

The amount, composition and type of petrochemical wastes usually depend on the characteristics of each unit process. In this study, wastes were classified according to Texas Environmental Protection Agency (EPA) and Basel convention was used to identifying hazardous wastes. Wastes were classified to four different groups: 1) hazardous and non-hazardous waste, 2) liquid and solid waste, 3) wood, plastic, glass, catalyst, oil and paper and 4) recoverable, reusable, recyclable, ignitable waste.

3. Results and discussion

3.1. Waste sources, generation and classification

Industrial solid waste (ISW) is generated from commercial and institutional activities as well as from petrochemical processes per second. The petrochemical solid wastes are generated by various processes that support industrial operations, and as such their generation rates are related to the nature and directly proportional to the extent of these processes. Plant offices, staff restaurant, laboratories, and other personnel-related activities, generate the non-process ISW.

Process solid waste comprises what remains or rotten of the raw materials used all along the chain of production processes. Wastes produced in the course of operation, repair and maintenance of industrial plants and machines also fall under this category. Packing materials for industrial products fall under the commercial/institutional category of ISW. Table 1 illustrates a list of generated wastes in MPC. In this study it was observed that solid waste from restaurant, which is stored in special containers, is collected every day. As it can be seen in Table 1, only 0.42% of wastes were produced by significant quantities of non-process ISW. For all practical purposes, the remaining 99.57% of the industries produce process ISW only.

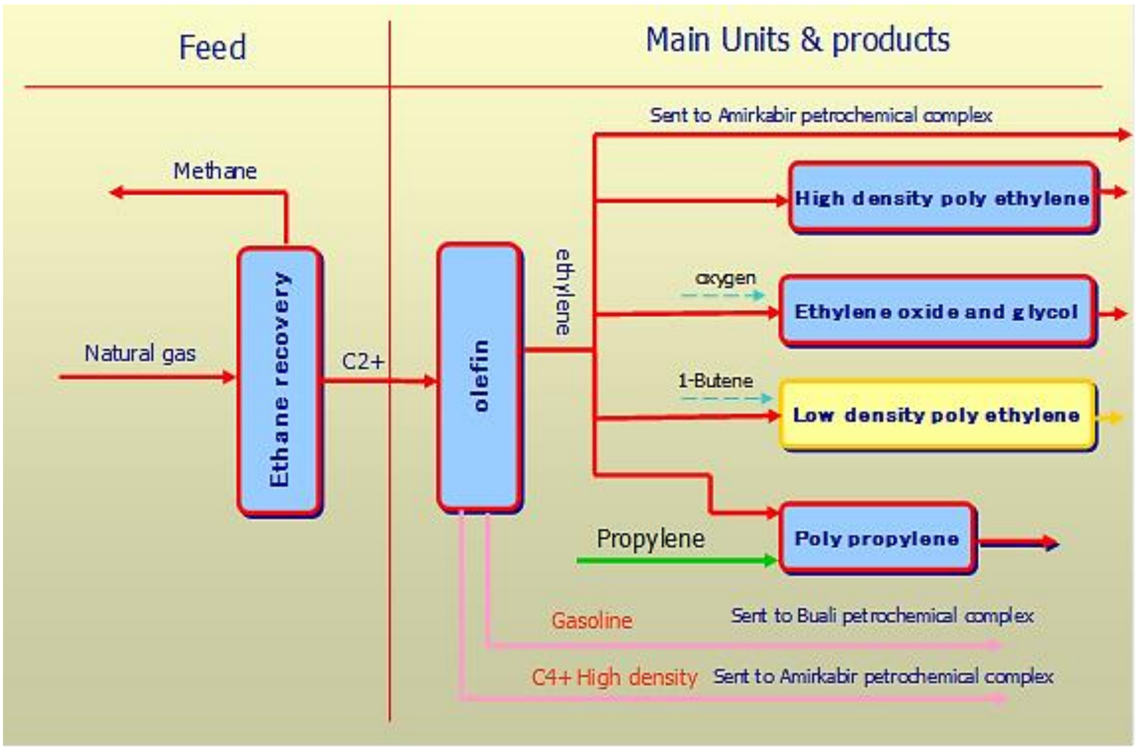

Figure 2. Brief process diagram of Marun petrochemical complex

Table 1. Generated wastes in Marun petrochemical complex

emission source*	waste type	liquid	solid	Waste stream
1, 3, 4, 5	empty container of chemicals		✓	4264 kg/month
2, 3, 8, 7	off specification products		✓	557.32 ton/year
2	waste hexane	✓		1100 ton/year
2	catalyst container		✓	20 kg/week
2	wax		✓	2000 ton/year
2	paper bag		✓	13 kg/week
1	Residue From re-claimed of MEA		✓	11 m3/year
1	spent catalyst		✓	16 m3/10year
1, 4	spent catalyst		✓	45.78 m3/2year
1	Spent absorbent drier		✓	234 m3/3year
1	spent catalyst		✓	63 m3/6year
1, 5	wooden pallet		✓	1000kg/month
1	coke		✓	145 ton/year
1	absorber		✓	14 ton/3year
1	activated carbon		✓	14.4 ton/1.5 year
1	ion exchange resin		✓	16 m3/2year
5	cationic and anionic resins		✓	3.5 m3/4-5year
5	anthracite and activated carbon		✓	485 lit/4-5year
5	eliminator		✓	302 m2/year
5	mud		✓	30 ton/5year
5	cooling tower packing		✓	231 ton/3year
4	NOR,TRB3 catalyst		✓	45 m3/6week

*1=Olefin unit, 2=high density poly ethylene unit, 3=Poly propylene unit, 4=Eo/Eg unit, 5=Utility unit, 6=Repairing, 7=Laboratory, 8= Store, 9=Central service field

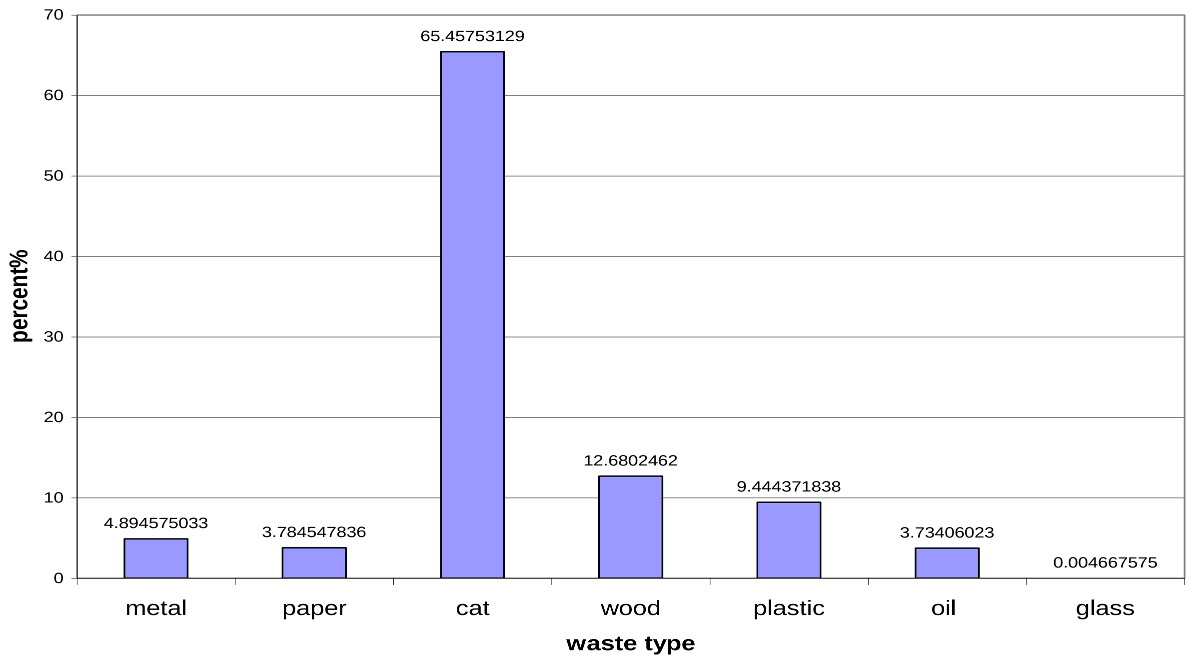

Figure 3. Composition generated waste in Marun petrochemical complex

Table 2. Present situation of waste management in Marun petrochemical complex

Recovery %	Recycle %	Landfill %	Store %	Incineration %	not managed %
1.435669	32.9088141	0	32.0739	0	33.5817206

After the analysis of industrial solid wastes of MPC, 63 source points of solid waste generation were determined being the reason for generation of 6199 tons solid waste yearly. As shown in Figure 3, the generated wastes in this petrochemical complex is consisted of 65.46% catalysts, 4.89% metallic materials, 9.44% plastic barrel, 3.78% paper, 12.68 % wood, 3.73% oil and 0.0046 % glass. As it can be seen, catalysts are the main part of the solid wastes. Physical properties analysis of generated wastes showed that 19.9% of these wastes were liquid and 80.1% of them were solid (Figure 4).

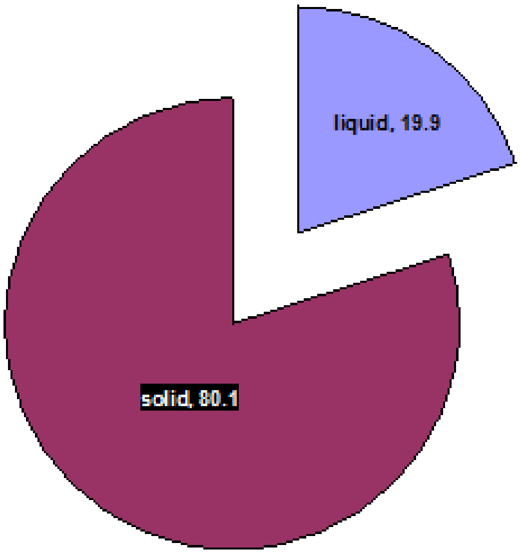

Figure 4. Waste classification based on physical properties

Waste classification based on the US EPA method as shown in Fig.5, determined that 81.94% of the generated solid wastes in this complex were hazardous and 18.06% of them were non-hazardous waste. Therefore, the hazardous waste such as catalysts and oil should be managed before disposal.

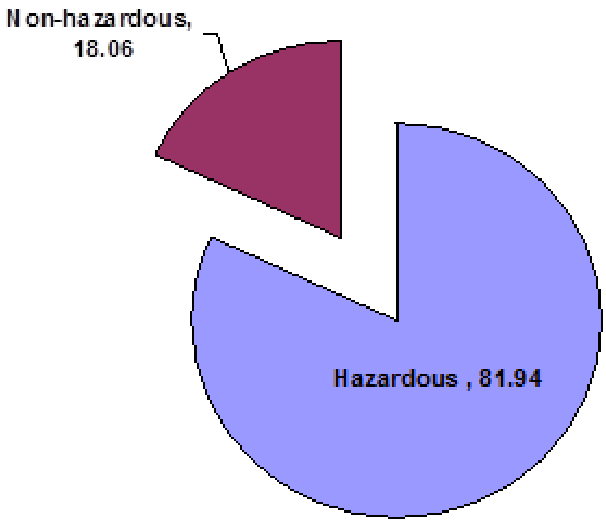

Figure 5. Waste classification based on hazardous properties

3.2. Present waste management system

The data in Table 2 shows that some wastes aren't managed properly. Correct management is that which takes into account activities without negative environmental impact as: minimization, reuse, recycling, recovering and elimination in sanitary landfill. Except off specification products which are sold, 32.07% of the generated wastes are stored and 32.91% of them are recycled. As shown in Table 2, there are some wastes (33.58%) that have considered no especial management practice for them because they will generate in future.

3.3. Future waste management planning

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). The elements of the hierarchy are.

Table 3. Anticipated results of MPC solid waste management in the future

Recovery%	**Recycle%**	**Landfill%**	**Store%**	**Incineration%**	**not managed%**
61.54855	31.5929234	4.371387626	0	2.48714	0

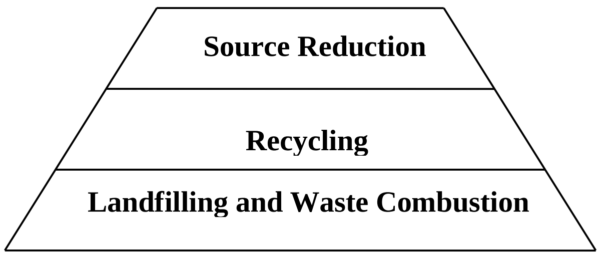

Figure 6. Integrated solid waste management hierarchy

The ''Waste Management Hierarchy'' has been adopted by most industrialized nations as the menu for developing solid waste management strategies. The extent to which any one option is used within a given country however varies, largely depending on a number of factors, such as topography, population density, and transportation infrastructure, socioeconomic and environmental regulations (Sakai *et al*., 1996). As discussed above, most of wastes which are generated in petrochemical industry have hazard potentials when they are discharged into environment without proper management. Some management procedures that we found to be best option for managing wastes are described in the following. Recycling reduces solid waste and produce beneficial materials; this represents an important business with a high potential for future development. Recycling is growing nationwide, encouraged by the economic and environmental benefits it brings. The successful implementation of recycling faces many difficulties such as low levels of awareness and the lack of appropriate funding. Recycling can be promoted by encouraging separation at the source. The best way of waste separation at the source can be stimulated by financial incentives, legislation and the raising of environmental awareness. Obtaining funds for solid waste management in developing countries requires tremendous effort and time.

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 packing of finished products. As shown in Table 3, 61.54% of wastes are recoverable and reusable and 31.59% are recyclable. Waste hexane has capable of recycling and reusing. Because of containing 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 toxicity. By implying in solid waste management system, no waste will be stored and it will be consider specific management for waste which will be generate in future. Therefore adverse environmental impacts of wastes can be mitigated; occupied space by wastes can be removed and extra income can be obtained.

Waste minimization has been placed at the top of solid waste management hierarchy. Waste minimization consists of two basic operations: source reduction and recycling (Hopper *et al*., 1993). Source reduction is most desirable to avoid waste generation, while recycling is useful to conserve resources and to prevent materials from entering the waste stream. Waste should be separated to recover the recyclable and reusable products. Along with the rapid industrialization and sustained economic progress was a higher standard of living for most citizens. The new bill favors waste minimization by emphasizing the manufacturer's duty to minimize process wastes (in the current law priority was given to prevention of waste generation). In third world countries, several problems may occur in waste minimization management such as lack of supervisors and environmental controller, absence of regulations regarding hazardous waste, lack of efficient technology, and anxiety of disorder in the process, being pessimistic about new procedures and also objection of organizations and industry managers to any changes. Due to these limitations, some procedures for industrial waste minimization in MPC are suggested as:

• Valuable metals recovery from used catalysts.

• Thermo recovery of used activated carbon.

• Neutralization and cleaning of hazardous waste containers, before their reuse and recovery or unless melting remained metal barrels contaminated with hazardous wastes.

• Finding proper applications to reuse spent aluminum ball, like using them as basic material in fire brick workshops.

• Training unit workers and operators about the importance of recognition of waste production sources for waste minimization and environmental protection and planning routine repairs of the unit.

• Enforcement of regulations associated with hazardous waste handling, collection, storage, transport and disposal, emphasizing educating and mobilizing society to segregate recyclables.

• Following technical standards in production processes, gaining minimization of units wastes.

• Create a research team out of process, operation and environment engineers in research and development unit to achieve the goal of studying about the newest and the most possible process which can be a proper supersede of the old units process; and also finding new materials introduced to markets with more environmental compatibility.

• Monitoring of waste minimization programs in the studying units and compensation for the weak points.

4. Conclusion

Questionnaires have been used as a tool to learn about the management of wastes in industrial areas, as well other types of wastes. The use of questionnaires in order 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 study. 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 is necessary in order to obtain more precise information. Except off quality products, catalyst, oil, absorber, resin and cooling tower packing are the most important waste types insomuch as volume is concerned. These wastes were classified depended on 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 there were some wastes that didn’t consider any management method for them. According to waste management strategies such as minimization, reuse, recycling, recovery and disposal, we chose the best options. 61.55% of wastes can be recovered, 31.59% of them can be recycled and 2.48% of them should be incinerated. Finally, some waste minimization ways were recommended. Proper waste management system helps us to mitigate adverse environmental impacts of wastes as well as its other benefits.

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