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Evaluation of solid waste recycling in Khazra Industrial estate, Iran

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ABSTRACT

Aims: The aim of this study was to determine and evaluate the potential methods for restoration of waste processing and recycling units in the Khazra Industrial region in Kerman, Iran.

Materials and Methods: The present research was a field study performed by organizing a questionnaire and implementing local surveys during 1 year. At first, detailed information of the status of the industrial waste production including its amount, composition, percent of components and percent of waste generated by each industrial zone was identified. Then the industrial sites present in each zone were classified in different groups. Furthermore, the various wastes produced in these industries were analyzed according to type, nature, recyclability, place of production, production frequency and quantity of waste.

Results: In the Khazra Industrial Park 97 industrial units are operating, with the approximate production capacity of 729670.5 tons different products a year, which make 26141 tons waste annually. Totally 41 types of waste are produced in Khazra Industrial Park, of which 9 types can be recycled.

Conclusion: Overall, our findings suggest that the total amount and the variety of waste generated, and the availability of waste-recycling units in the park hinder the establishment of any recycling and processing units in the Khazra Industrial Park as they are not economically efficient. Therefore if the park development plans get going and by using economic initiatives, the foundation of processing and recycling units in this industrial park is recommended and will have economic and environmental benefits.

Key words: Evaluation, industrial park, Kerman, management, recycling units, solid waste

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INTRODUCTION

Industries have an important role in the development of regions and countries. As industries grow and concentrate in industrial regions, the increase in waste production on one side and the lack of necessary regulations for the

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management of this material on the other side has made many regions in the world face serious challenges and has led to many environmental threats.[1,2] Regardless of the executive management of industrial waste, which has not been done well, in most circumstances the disposal of these waste is associated with a lot of trouble and in most circumstances, is managed in a way that leads to environmental pollution and encounters the natural ecosystems and human health with many hazards.[3,4] Currently, the industrial waste is burned unsanitary or enters soil and water and therefore, pollutes our water and land.[5,6] One of the best, most economic and most environmental friendly industrial waste management activities is recycling.[7,8] In the past, the waste management mainly included collection, burning and disposal in land and there was no attention toward the recycling of industrial waste. As time passed with progress in science and technology, environmental knowledge increased and the relations between the environment and human health became more obvious.[9,10] On the other hand, the limitations of material and water resources due to population increase and excessive uses became clearer and people realized that waste burning and dumping is associated with many problems and leaves serious negative environmental consequences. Also, waste burning and dumping cannot solve the problem of increasing volumes of waste production.[11-13] Therefore, after a while recycling was described and it was clarified that we can use this method for managing industrial waste.[8,14] The production of material and energy, increase in the efficacy of industrial waste management, creating jobs, environmental sustainability and sustainable development are the aims of recycling.[15,16] Until 1980, the recycling of industrial waste was limited to demand and the recycling programs were managed based on supply and demand. From 1980, the issue of recycling industrial waste, was reformed and found a special place in the management of industrial waste. For this reason from the 1990s, industrial waste management was built on the main core of recycling.[17,18] Fortunately, in the recent years a lot of attention has been paid to industrial waste management in Iran and with formulation of related rules and regulations an appropriate legal framework for an increased level of industrial waste management is provided.[10,19] On the other side, the economic and engineering justification of the industrial recycling process has persuaded local professionals to design and practice the industrial process of recycling and it is predicted that if these recycling units are supported by the banking system and increased investment is done in this section, along with its economic justification, we will witness the fast increase in recycling units.[17,20] In this study, the possibility of establishment of recycling units at the Industrial Parks of Iran, by studying one industrial parks in Kerman ,the Southeast of Iran, is evaluated.

MATERIALS AND METHODS

This research is a descriptive cross-sectional study. The research method was based on field studies and through questionnaires, local visits to Khazra Industrial Park, and interview within 1 year beginning in 2009 until the end of 2010 has been done. The Khazra Industrial Park, with 564 hectares of land (the first phase), is located at the latitude and longitude of 56°, 52'N and 30°, 12'E of the Kerman province, respectively. The aim of this questionnaire was to collect information about waste management and its steps including production, on site storage, collection, transfer, process, recycling and disposal. The industries operating in the industrial parks are under the supervision of the Kerman province Industrial Park's Company. Therefore, after visiting the industrial parks and explaining the aims of the research for managers in-charge and acquiring their approval, the data necessary for the study was collected. At first, accurate data about the situation of industrial waste production including its amount, composition, percent of components and the rate of waste production by each industry was determined. Then with study on different industrial zones, the units in each zone were classified in different groups and the waste produced in these industries was identified base on the type, the physical nature, recyclability, the place of production, frequency and the annual waste production. Furthermore, the produced waste in different areas of the industrial park was evaluated qualitatively and quantitatively.

RESULTS

Determination of the rate of waste production and recognizing its increasing or decreasing trend and determining the qualitative and quantitative changes of industrial waste through time and location is one of the most important management tools in different stages of industrial waste management.[15] On the other hand, recognizing sources, the quantity and quality of the produced industrial waste has an important role in controlling the function of other activities related to industrial waste management.[21] Currently, there are eight active industrial zones in this park which consist of the chemical, metal, mineral, non-metal, textile, food industry, services, cellulose and electronics. From the 278 industrial units, 97 ones operate with the approximate products of 729670.5 tons a year with 26141 tons waste generation per year. The situation of industrial units in different areas of the park has been shown in Table 1. According to the capacity surveys in the Khazra Industrial Park, the average of waste production per each unit production is 48 km (0.048 tons) of waste and this amount is different for different zones depending on the various industries operating in each zone [Table 2]. The total amount of waste production in the Khazra Industrial Park is 71600 km a day and 26141 tons annually, in which 21912 tons is industrial waste and the rest, which is 4229 tons is special waste. In Table 3, the rates of industrial waste production in the Khazra Industrial Park area and their percentages have been shown.

In the Khazra Industrial Park, the industrial units operate in different groups, which include food, construction,

textile, chemical, machinery, cooling systems and other industries. Considering the various operating industries, the classification of industrial waste produced in this park is based on the type of waste and therefore the industrial waste is divided into 11 groups and has been shown in Table 4. This classification was done based on the nature of these wastes and its management method until disposal. The highest amount of waste produced belongs to the metal zone and the construction and demolition wastes, which is 16500 tons a year and the reason is the high density of this material. The lowest amount of waste production, which is 8 tons/year belongs to metal non-iron metal waste.

Of 97 active industrial units on Khazra Industrial Park, 86 generate solid and 4 generate semi-solid wastes. It should be noted that based on comments of the owners of seven industrial units, these industries do not produce any industrial waste. Therefore, 88.7% of the active industries in the Khazra Industrial Park produce solid industrial waste.

Because eight different industrial regions are active in this park, the produced industrial waste has a wide range and the variability of the produced waste necessitates that the waste management plan be prepared thoroughly.[22] Therefore, the industrial waste in this park is classified according to the regional divisions and in Table 5 the type and the rate of industrial waste production based on the divisions in the industrial park have been shown and classified.

Table 1: The operating situation of different industrial units in different zones of the Khazra Industrial Park

The industry	Number of units	Percent from total units	Number of active units	Percent of all active units
Chemical	70	25	34	35
Metal	59	21	19	20
Food	51	18	15	16
Mineral, non-metal	32	12	13	13
Electronic	15	5	7	7
Textile	14	5	5	5
Cellulose	11	4	3	3
Services	26	10	1	1
Total	278	100	97	100

Table 2: The rate of waste production in active zones according to the product of each unit

The industry	Number of units	Capatown (tons per year)	The amount of waste production per each ton capatown (kg)
Chemical	34	314480	5
Metal	19	190000	50
Mineral, non-metal	13	96750.5	60
Electronics	7	5750	90
Textile	5	15400	70
Food	15	96390	2
Cellulose	3	10900	60
Services	1	0	0
Total	97	729670.5	337

Table 3: The amount of industrial waste produced in the regions of the Khazra Industrial Park

Industrial regions	The rate of waste produced (tons in year)	Percent from total
Chemical	3009.4	11.5
Metal	12418.64	47.3
Mineral, non-metal	6398.43	24.4
Food	218.25	0.9
Electronics	523.962	1.99
Textile and leather	1027.3	3.91
Cellulose	2645	10
Services	0	0

Table 4: The type and rate of industrial waste production

Type of waste	Rate of production per year (in tons)	Percent
Polyethylene and polypropylene wastes	1773	8
Metal iron	2036	7.9
Metal non iron	8	0.02
Wood wastes	560.35	2.5
PET	22	0.06
Glass wastes	50	0.23
Paper and cardboard	700	3.2
Dust	11	0.05
Organic waste	520	2.4
Textile waste	75	0.34
Construction and demolition waste	16500	75.3
Total	22255.35	100

PET: Polyethylene terephthalate

DISCUSSION

The current situation of recycling industrial waste at the Khazra Industrial Park

It is worth mentioning that the waste of most industrial units at the Khazra Industrial Park can be recycled and reused by other industries. These materials are bought by the private industries or scavengers and generally has many adverse environmental and health effects. Unfortunately, from the viewpoint of the industrial managers selling the waste for the highest price is the priority and the fact that how and by whom the waste is recycled and where it ends after it is sold is of lesser importance. This fact can lead to serious health and environmental problems in the future.

As shown in Table 5, totally 41 different kinds of waste is produced at the Khazra Industrial Park, and from these wastes 9 kinds are recyclable, which are the polyethylene, polypropylene and foam, iron metals, non-iron metals, wood wastes, polyethylene terephthalate (PET), glass wastes, paper and cardboard, organic waste, construction and demolition wastes.

Polyethylene, polypropylene and foam

The rate of production of these wastes in a year was 1753 tons in the park that is 5 tons a day. Considering the fact

Table 5: Annual amount and percentage of waste produced in each zone of the Khazra Industrial Park

Industrial waste (tons per year)	Chemical	Metal	Mineral, non-metal	Food	Elctronics	Textile	Cellolose	Services	Total
Polyethylene and polypropylene wastes	600.8	112.6	292.98	29	10.502	31	0	0	1076.9
Metallic wastes (iron)	303	257	100	6	158	62	0	0	886
Copper wastes	0	0.74	0	0	2.96	4.3	0	0	8
Wood wastes	502.6	6	6.75	0	0	45	0	0	560.35
PET	8	0	11.2	2.75	0	0	0	0	21.95
Metallic containers	1000	0	150	0	0	0	0	0	1150
Polyethylene containers	500	0	100	0	0	0	0	0	600
Glass wastes	0	50	0	0	0	0	0	0	50
Paper and cardboard wastes	2	1.5	34	10.5	1	0	45	0	94
Acidic solutions (m^3)	0	800	0	0	0	0	0	0	800
Oil wastes (L)	0	300	0	0	0	0	0	0	300
Foam	0	0	6	0	0	90	0	0	96
Dust	0	0	7.5	0	0	0	0	0	7.5
Citrus fruit	0	0	0	166	0	0	0	0	166
Fish factory wastes	0	0	0	4	0	0	0	0	4
Textile and dyes wastes	0	4	0	0	0	75	0	0	79
Film and zinc (number)	0	0	0	0	0	0	2000	0	2000
Oily bentonite	0	0	0	0	0	360	0	0	360
Stone wastes	0	9500	5600	0	0	0	0	0	15100
Silica	0	417.2	0	0	0	0	0	0	417.2
Water and soap solution	0	4	0	0	0	0	0	0	4
Gas	0	0	0	0	0	0	0	0	0
The paper and cardboard factory wastes	0	0	0	0	0	0	600	0	600
Aluminum waste	0	0	0	0	0	0	0	0	0
Treatment plant wastes	0	0	0	0	0	0	0	0	0
Soil	90	0	0	0	0	0	0	0	90
Carbon wastes	3	0	0	0	0	0	0	0	3
Tar and perlite wastes	0	360	0	0	0	0	0	0	360
Lining wastes	0	1	0	0	0	0	0	0	1
Polystyrenes (m^3)	0	520	0	0	0	0	0	0	520
Pottery wastes	0	3.6	0	0	0	0	0	0	3.6
Carpet wastes (kg)	0	2	0	0	0	0	0	0	2
Cotton (kg)	0	20	0	0	0	0	0	0	20
Noninflammable material	0	14	0	0	0	0	0	0	14
Cotton seed wastes	0	0	0	0	350	0	0	0	350
Sponge and leather	0	0	0	0	1.5	0	0	0	1.5
Oil treatment plant wastes	0	0	0	0	0	360	0	0	360
Construction and demolition waste	0	0	90	0	0	0	0	0	90
Total	3009.4	12418.64	6398.43	218.25	523.962	1027.3	2645	—	26241
Percent of total wastes produced in each zone %	11.5	47.3	24.4	0.9	1.99	3.91	10	—	100

PET: Polyethylene terephthalate

that there is a factory for plastic recycling operating in the industrial park, this factory can be used for recycling plastic and making new products. In this case, it is necessary to design an active mechanism for collecting and delivering these wastes to the recycling factory with the cooperation of the industrial managers. These wastes are a major challenge for recycling due to their high volume and low biodegradability.[23] In a study done by Bocci *et al*. in Italy in 2000, disposed plastic specially low-degradable and hard plastics were used for making concrete and showed to be a suitable substitute for part of the rock composition. Furthermore in a study done by Al-Salem *et al*. in 2009 in England, authors studied the routes for reusing and recycling disposed plastic, and mentioned four ways for reusing plastic waste, which included primary reuse, mechanical reuse (secondary reuse), chemical reuse (pyrolysis, gas production) and energy reuse and among these methods, the technology of chemical reuse and energy production was the most beneficial.[24,25]

Iron metals

There is a high production of these wastes and reaches 2036 tons per year, and because the iron wastes do not need recycling and can be reused at the steelworks, selling these wastes to the steelworks is profitable. Recovery of metals and its utilization are important not only for saving metal resources, but also for protecting the environment. Meawad *et al*. in 2010 in Bolgaria studied recycled metals from the solid waste of a thermal power plant by using mineral processing technologies, hydrometallurgy and biological hydrometallurgy and recycled metals such as ferrous, chromium, nickel and magnesium.[26]

The non-iron metals

The annual production rate of these wastes is 4 tons and is generally related to the electric industries. The main metal in these wastes is copper, which has the highest value. This group can be sold in the market. In a study done by Metin *et al*. in 2003 in Turkey by proper management of municipal solid waste, recycling and reusing of non-ferrous metals such as aluminum, copper, lead and silver are used widely in industrial scale.[27]

Wood waste

This part is mainly made from wooden plates and if sound, can be reused in the waste storage sector of the industrial unit. Furthermore, the damaged and unusable wood waste can be used in the factories that use wood waste such as cardboard and chipwood factories.[28] It should be noted that the rate of production of these wastes in the Khazra Industrial Park is 560 tons a year. In a study done by Obata *et al*. in 2006 in Japan, recycled wood waste was used as an industrial source and as a method for long-term storing of fixed carbon from carbon dioxide of photosynthesis. Also in a study done by Rivela *et al*. in 2006 in Spain and Krook *et al*. in 2008 in Sudan, wood waste was used for making wooden panels and producing heat.[29-31]

PET

Although these wastes are part of the polymeric material, but because of their different way of recycling they are classified in a different group. PET has the ability to change to the granular materials which feeds the petrochemical factory. Therefore, this group of waste can be used several times and after its form is changed it can be recycled again and used in second-grade plastic industries such as synthetic leather industry, lining materials manufacturing and etc. The results of the studies done by Bocci *et al*. in 2000 in Italy confirmed that there is a possibility to use derived plastic for making bituminousconcrete.[25] In Iran, PET is increasingly being used in the packaging of beverages. Therefore, the recycling of this waste will be economical and necessary. Currently in Iran, the reuse of PET to make initial materials is not economic and cannot be done due to lack of proper technology. These materials are used in making shoes, lining materials, decorating objects and etc. Considering the operation of a factory producing PET at the Khazra Industrial Park and the possibility of recycling these wastes, the waste can be reused in this factory. The 14 ton annual production makes its reuse reasonable and applicable. Plastics are the main pollutant in aqueous environments and consuming it by sea gulls and other animals is a major concern for environmentalists.[32]

Glass waste

The glass waste produced at the Khazra Industrial Park is 50 tons annually. These wastes which can be recycled, and can be dangerous too, because broken glass can damage machinery or harm workers during the process. Furthermore, it can interfere in the process of processing and recycling. Thus, it is necessary to collect these wastes by special management and transfer them to the glassworks. This group of waste can be reused at the glassworks and bottle-making factories. In a study performed by Ferraris *et al*. in 2001 in Italy, glass matrix composites were obtained by mixing low-cast ashes produced at municipal solid-waste incinerators and aluminium factories.[33]

Paper and cardboard waste

The production rate of these wastes in the Khazra Industrial Park is 700 tons a year, which is a noticeable amount. Much of this waste is cardboard which is related to the packaging of goods.[34] Given the presence of a recycling unit inside the park and high levels of waste paper and cardboard, this category of wastes can be recycled within the park and be transported to paper mills. According to a statement from the managers of the cardboard recycling factory, this unit cannot recycle paper. Thus, the amount of paper produced should be moved out of the park for recycling. Among waste materials, solid waste from the pulp and paper industry has been of much concern because large amounts of solid waste are generated during the processing. They were managed using several approaches including land filling, incineration or mixing in cement or brickworks.[35] In a study done by Lertsutthiwong *et al*. in 2006 in Thailand, the solid waste from the paper mills was used as material for producing cardboard.[36] Furthermore, Lertsutthiwong *et al*. in 2008 used solid waste from the paper mills and from corn husk for making cardboard with low heat conductivity.[37]

Organic waste

The amount of organic waste production at the Khazra Industrial Park is 520 tons annually and is from the food industry, flour industry, cannery and etc. The amount of waste due to low generation capacity cannot be converted to compost, but it can be used for producing animal food, which its factory is operating in the park. Solid and liquid organic waste from the residential area or industrial processing can provide the recyclable, raw material for producing biological fertilizers and biogas. The most well-known method for recycling and management of organic waste is composting process. In this process, organic waste such as domestic waste or waste from food industries is converted to compost. This process is not only efficient and beneficial, but also environmental friendly.[13,38]

Construction and demolition waste (c and d)

This group of waste includes the waste from the stone cutting and masonry units and makes the majority of waste produced at the Khazra Industrial Park which is 16500 tons a year and a major part of it is non-metal minerals. Up to now, no attempt has been made to manage this waste by the responsible bodies. The results of a study performed by Huang *et al*. in 2001 in Taiwan, clearly showed that construction waste has a good potential for

recycling and after removal of contamination, this waste can be used as a context of roads or as a covering material at sanitary landfills.[39] Also studies from Yuan in 2011 in China showed that recycling construction waste through closed circle (converting material to different products) is socially and environmentally better than through open circle (converting material to the same product).[40] Thus recovery procedures and the use of such wastes proposed as follows: Using them as a covering at sanitary landfills, Using them as road infra-structure, Sand production and recycling and its usage in the cement industry, Using them for making artificial hills and environmental aesthetics, Using them for leveling land outside the park, with the cooperation of Kerman Environmental Protection Department, Using construction and demolition for earth endams construction and flood control.

Based on the available methods these wastes can be used as mentioned above according to their particle size. For example, the stone powder can be used in the cement and construction industry.

Determining and evaluating the possible ways for establishing waste processing and recycling units at the Khazra Industrial Park

Considering the total rate of waste produced at the Khazra Industrial Park which is about 26141 tons/year and the variety of waste produced and on one side the presence of units that currently have the potential to recycle some of the park's waste, the establishment of recycling and processing units in the Khazra Industrial Park does not seem economic. Providing park preparation and implementation of industrial development plan and use of economic solutions the establishment of a processing and recycling unit can be justified economically and environmentally. In order to evaluate the subject of establishing processing and recycling units more closely, this was examined from two aspects:

Not establishing processing and recycling units

Currently the industrial waste produced in this park is either sold or is disposed (by contractors) through different ways. Considering three active industrial units with the ability to recycle some of the wastes produced in this park that is plastic, cardboard and PET recycling units, it is possible to recycle the waste produced in the park according to the sanitation principles and by economic benefit. Other industrial waste which is about 19760 tons a year has to be transferred to other locations where their recycling is possible such as ironworks or sold in the market. Because the units mentioned above are in the industrial park, the cost of recycling decreases considerably. On the other side, the park's waste management system undergoes less cost for collection, transportation and processing.

Establishing processing and recycling units and its economic initiatives

One of the other considerable options is the possibility of establishing a recycling unit within the industrial park. This unit has to be able to recycle most of the groups of industrial waste produced in the park. To accomplish this it is necessary to consider a place within the park especially in the central part of the park development plan as a processing and recycling center for industrial waste so that investors can launch proper recycling units for the industrial waste from here and from the Kerman province. In order to make the activities of this center economic, it is necessary to transfer the waste from other industrial parks in the province and even neighboring states to this center following qualitative and quantitative studies. In this case, this industrial park can become the recycling hub of the province and regional industrial wastes.

To implement the project, it is necessary to provide the center with proper facilities from governmental and private sources.

In order to attract domestic and foreign capital for the construction of the processing and recycling industrial waste center at the Khazra Industrial Park following suggestions are offered: Direct investment by the private sector, A joint venture between the private sector and organizations for small industries and the industrial park's of Iran, to achieve sustained development and environmental fundamentals and in order to create the first industrial eco-park in Iran, Using the investment of foreign companies with an approach to localize there cycling technology in Iran, Using international aid in the form of Global Environmental Facility, Japan International Cooperation Agency and United Nation Industrial Development Organization projects and other international environmental facilities.

Some other factors that are also effective in development and success of the recycling industry are listed below: Country's overall policy in regard to industrial waste, Approved laws, regulations, and guidelines, Estimated technical potential of the recycling industry in the country, the support and supervision of relevant ministries and organizations, Knowledge and awareness levels of managers of industrial units, Economic factors and the support tools of the industrial units.

CONCLUSIONS

In the Khazra Industrial Park 97 industrial units with the approximate production capacity of 729670.5 tons a year are active and they produce 26141 tons waste a year. According to the estimate survey done in the Khazra Industrial Park, the average waste generated per unit of production capacity is 48 km (0.048 tons) of waste and for each production zone this figure is different due to a variety of industries located

in each zone. Totally 41 kinds of waste are produced at the Khazra Industrial Park. The highest amount of waste produced is from the construction and demolition wastes group and is 16500 tons a year and the reason is the high density of these materials and the lowest amount of waste which is 8 tons a year is the non-iron metal wastes. From the 41 different kinds of waste generated in this park, 9 kinds are recyclable. Considering the total amount of waste produced, the variety of waste produced, which lowers the levels of each group of waste as well as the existence of units, which have the potential to recycle some of these waste, the establishment of any recycling and processing units in the Khazra Industrial Park does not seem cost-effective economically. Therefore if the preparation and development plan of Khazra Industrial Park are implemented and with economic solutions, the establishment of processing and recycling units in this park can be recommended due to the economic and environmental interests.

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