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Article *in* Environmental engineering and management journal · December 2015

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December 2015, Vol.14, No. 12, 2793-2807
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INDUSTRIAL SOLID WASTE MANAGEMENT IN THE GOVERNORATES OF NABLUS AND RAMALLAH & AL-BIREH, PALESTINE

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Abstract

In Palestine, environmental problems associated with industrial solid waste (ISW) have increased significantly in recent years. This paper presents survey results on current industrial solid waste management (ISWM) practices in the governorates of Nablus and Ramallah & Al-Bireh, Palestine. Solid waste generated from industries was quantified, characterized and discussed in terms of generation rate, storage, reuse/recycling, transportation, and final disposal. An attempt was made to compare ISW components among Middle East countries or cities. The quantities of ISW in an order of the largest generator are 2044.2 tonne/year by basic chemical industries, 1973.5 tonne/year by food and drink industries, and 1807.0 tonne/year by pulp and paper industries. The paper, pulp, wood, and furniture industries that comprise only 3% of the total industries produce 47.7% of total ISW. 32.4% of the industries always separate their wastes into different components. 88.4% of the industries store ISW temporarily in containers. Plastic, wood, papers, and metals are the main waste materials that are being reused and/or recycled. 25.9% of the industries use recycled material as raw materials and 25.9% sell it to other companies. 39.4% of the industries transport their waste to final disposal sites on a daily bases. 68.8% of the total ISW generated is disposed of at either dumpsites or landfills. It is recommended that the ISWM that emphasizes maximizing recycling quantity and minimizing landfilling quantity be carried out through implementation of the "cleaner production" principle introduced by the United Nations Environment Programme, in all industries in Palestine.

Key words: industrial solid waste, solid waste management, waste characterization, waste management practices

Received: March, 2012; Revised final: October, 2012; Accepted: November, 2012

1. Introduction

Solid waste generated from industrial activities often contains materials that are more hazardous than those from domestic activities (Al Naimi et al., 2015; El-Fadel et al., 2001; Patrício et al., 2015; Rosado et al., 2014). As compared to municipal solid waste (MSW), therefore, industrial solid waste (ISW) has potentially greater adverse effects on the environment and poses higher risks to the public. The growing quantity of ISW is a major problem in many parts of the world (Behera et al., 2012; Sarkady et al., 2014). The problem is more serious in a developing world, particularly those countries that are undergoing rapid industrialization and urbanization. It has been known that an absence of a program or an ineffective program for industrial solid waste management (ISWM) can lead to water, soil and air pollution, which, in turn, leads to public health problems (Hidalgo et al., 2014; Niza et al., 2014).

In Palestine, the potential of economic growth lies with the private industrial sectors although there are a limited number of large enterprises: only about 100 manufacturing, mining, and construction companies have a workforce of more than 100

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employees. Palestinian businesses are dominated by small to medium-size, single owner, family enterprises. This industrial sector absorbs about 13% of the total labor force, and their contribution to Gross Domestic Product (GDP) is about 16% (Palestinian Federation of Industries, 2009). In the West Bank and Gaza Strip of Palestine, there are currently about 15,000 registered industrial firms. The types of industries that characterize Palestinian industrial sectors are metal and engineering, food and beverages, stone and marble, textiles, garments and leather, wood and furniture, printing and packaging, plastic and rubber, handicrafts, chemicals, pharmaceuticals, paper, glass, and electrical equipment (Filfil and Al- Khatib, 2000; Khatib and Al-Khateeb, 2009; Musleh and Schmidt, 1998). These industrial sectors are active components in the economic development of Palestine (Ministry of National Economy, 2004; Palestinian Federation of Industries, 2009).

To fulfill demand by the local market and to take advantage of opportunities sporadically available for them to export products to neighboring and European countries, the number of factories and the rate of industrial production are increasing each year. At the same time, the rate of waste generation and seriousness of environmental and public health problems are increasing. Therefore, studies are urgently needed to identify current ISWM practices that are being taking place in these industries and assess how well the ISWM systems are working.

This paper presents a case study with ISWM in the governorates of Nablus and Ramallah & Al-Bireh in Palestine. Presently, little information is available about ISWM in these governorates. The quantities and characteristics of ISW that is being generated, reused/recycled, stored, transported, and disposed of in Palestinian municipalities are unknown, though such data are essential for examining and improving an ISWM system (Musleh, 2006).

Nablus and Ramallah & Al-Bireh Governorates represent a major economic, political, cultural and industrial center for Palestinians, and all types of industries that represent Palestinian economy exist in this region. Further, these two governorates are currently facing serious problems with large quantities of ISW, environmental pollution, and potential human health risks. The specific objectives of this study are to: i) estimate quantities and determine characteristics of ISW generated from industries; and ii) examine current ISWM practices including segregation, storage, treatment, reuse/recycling potential, and final disposal.

Data was obtained by interviewing factory owners, managerial staff, or ISWM staff. Efforts to compare the ISW components were carried out via extrapolation from data gathered from literature. Comparative results are presented in a graphical form, which allows visual comparison with selected Middle East countries or cities. Although this study was conducted in the selected Palestinian governorates, results obtained should provide perspectives relevant to other Palestinian governorates and many developing countries. Prior to this study, no comprehensive ISW investigations have been conducted at either Nablus or Ramallah & Al-Bireh Governorates.

2. Methodology

2.1. Study area

The study area is comprised of primarily industrial sites in the governorates of Nablus and Ramallah & Al-Bireh in Palestine. Nablus Governorate is located in the northern part of the West Bank, surrounded by the city of Jenin to the north, Tulkarem to the West, Ramallah and Jericho to the south, and the Jordan River to the east (Fig. 1). Nablus Governorate is comprised of 64 localities with a total population of 315,956 in 2007 according to the Palestinian Central Bureau of Statistics (PCBS, 2009). Ramallah & Al-Bireh Governorate is located in the central West Bank, 16 km to the northern border of the Jerusalem, and 48 km to the Mediterranean Sea. Ramallah & Al-Bireh Governorate consists of 75 localities, and has a population of 262,941 in 2007 (PCBS, 2009). There are many waste dumpsites: an individual community has its own dumpsites which were randomly created without proper socioeconomic, scientific, and engineering considerations. Samhan (2007) presumed that each build up area has its own solid waste dumpsite in Ramallah &Al-Bireh Governorate.

2.2. Industrial solid waste survey

A survey population is comprised of all industries in the governorates of Nablus and Ramallah & Al-Bireh. In the beginning of the field survey, an exploratory study was conducted in coordination with the Ministry of National Economy (MoNE). The purposes of the exploratory study were: i) to identify and locate all industries in the study area; and ii) to collect data on types, activities, processes, and current operational status of these industries. A field survey was designed and administered to a sample of 277 industries. A simple but structured questionnaire was prepared and pre-tested. Descriptive statistics such as means and ranges were computed using the Statistical Package for Social Science (SPSS version 16) computer program. From March to May of 2010, face-to-face interviews were held with owners, managers, or personnel in charge of ISW management of the industries. The questionnaire aimed to collect the following information; locations of industries, manufacturing technologies, production processes, raw materials, products, ISW management processes (reuse, recycling, separation and disposal), types of ISW being collected, availability of collection services, equipment and vehicles, collection fees,

final disposal methods, locations and types of disposal sites, demographic characteristics of the owners or managerial staff, managerial views toward ISW, perceived problems with current management systems, and other relevant issues.

Alongside the interviews, on-sight observations of the ISW and ISWM practices were also performed at all visited industrial sites. In addition, an in-depth personal interview with the director of the Environment Quality Authority (EQA) in Nablus Governorate was conducted during the field work.

While face-to-face interviews were held with representatives of 277 industries, an on-site survey on the ISWM operations was conducted with 108 industries. The on-site survey lasted for six consecutive working days as most of the industries work 6 days in the week in order to have a reliable data representing the generation rate of all working days, and targeted segregation of waste to determine compositions and characteristics of ISW. Industry samples were selected as follows. First, all industries were categorized into two governorates with the help of personnel from the MoNE. Second, representative industries were selected randomly from each governorate category. To select representative industries, various factors were taken into consideration, including level and modernity of the technology being used, industry category, and production capacity and its scale (Mbuligwe and Kaseva, 2005). An industry category was determined according to the Standard Industrial Classification (SIC) system.

2.3. Waste characterization and quantification

The ISW characterization and quantification stages included collection of ISW from appropriate places, separation of target components from bulk ISW collected, and weighing both segregated components and bulk ISW.

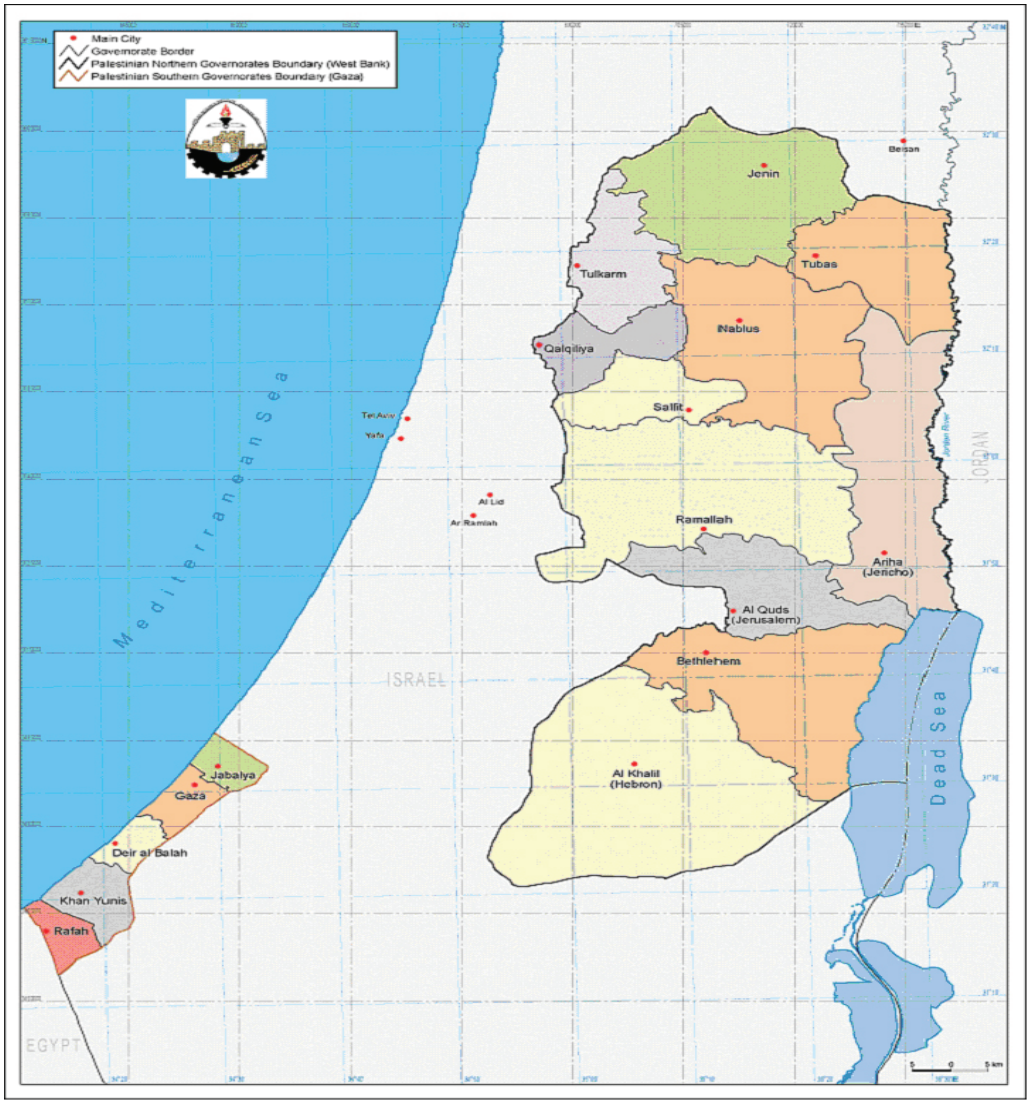

Fig. 1. Palestine map including the study area (ARIJ, 2005)

The target components include papers and cartons, plastic, glass, metals, remnants of plants, sludge, dust and soil, sand, rubber, solid chemical waste, and others. ISW was collected from appropriate sampling locations of the industrial facilities, and target components were separated within or beside the facility depending on a space available for the separation and weighing of the collected waste. Both bulk waste and segregated components were placed in different dustbins, each with a 80 litre capacity, and weighed, following the steps: (1) weigh an empty dustbin to determine its weight, M_E (kg); (2) fill the dustbin with bulk waste, then weigh the bin to determine the total weight, M_T (kg), and (3) determine the waste generation rate, W_G (kg/day) using Eq. (1):

$$W_G = \left[\sum \left(M_T - M_E\right)\right] / t_d \quad (1)$$

where t_d is the duration of time for which waste is collected (day).

To facilitate ISW characterization, solid waste was segregated based on desired ISW classes, which were selected based on waste types and sources. After the segregation step, each waste component was weighed separately. The total quantity (weight) of waste component, Ec, was computed using Eq. (2):

$$E_C \text{ (kg)} = R_C E_T \text{ (kg)} \quad (2)$$

where R_C is the ratio of the weight of segregated component to the total weight of bulk waste generated from a particular source, and E_T is the total weight of bulk waste generated from the same source.

Percentages of each component segregated from the bulk ISW were computed based on weight.

2.4. Waste categories

ISW is generated at various stages of industrial processes and non-processes. Non-process ISW is solid waste that is generated from, for example, staff cafeterias and canteens, laboratories, offices, and other personnel-related activities. Non-process ISW is divided into institutional and commercial solid wastes (Mbuligwe and Kaseva, 2005). Solid waste generated from educational, health care, correctional and other institutional facilities is classified as institutional solid waste, and that from stores, offices, restaurants, warehouses, and other non-manufacturing activities, excluding residential and industrial activities, is classified as commercial waste. Institutional and commercial ISW are, therefore, results of non-process activities, and their generation rates are related to the nature of waste and proportional to an extent of the commercial and institutional activities (Al Sadi, 2009).

Packaging materials are included in the category of commercial and institutional industrial solid waste. Process ISW, on the other hand, includes the rest of the materials generated through a series of industrial production processes. The process ISW category includes waste materials produced during not only manufacturing, but also repairing and maintaining industrial machineries and facilities.

3. Results and discussion

3.1. Demographic distribution of interviewees

The demographic distribution of interviewees is presented in Fig. 2. Among the 277 interviewees (i.e., industries), 90.3% are males and 9.7% females. Besides, 19.3% are factory owners, 39.2% managers, and the remaining are other personnel (e.g., engineers, supervisors). 45.1% interviewees received a post high school education, 43.3% high school education, and the remaining received only elementary school education. The highest percentage (48.4%) of interviewees live in cities, 43.7% live in villages, and the remaining reside in refugee camps.

3.2. Characteristics of industries

The general characteristics of the industries in the governorates of Nablus and Ramallah & Al-Bireh are presented in Fig. 3. Among the 277 industries surveyed, the private sector owns almost all (99.3%) of the industries. 38.4% of the industries started their operations within the last ten years and only 8.2% have been in operation over 20 years.

The highest percentages (40.1%) of industries have 3 to 10 workers, while the lowest percentage (8.3%) have more than 25 workers. The daily work hours range from 7 to 10 hours with 61.5% industries and 90.9% of the workforce. While 57 % industries are located in industrial areas, 43% are in residential areas in cities and villages commingled with dwellings. It is apparent that most of the industries have been established without adequate planning and/or a clear vision.

Location of industries within or near residential areas may be a contributing factor to environmental pollution and public health problems (Şchiopu et al., 2007). The composition of the industrial sector in Nablus and Ramallah & Al-Bireh Governorates is shown in Fig. 4. Also included in this figure are industries in Kuwait (Alhumoud and Al-Kandari, 2008) and Lebanon (El-Fadel et al., 2001) for the purpose of comparison.

Industries are grouped into the following categories: 1) paper, pulp, wood, and furniture; 2) textile, fabrics, apparels, and leather; 3) food, beverage, and agriculture; 4) oil and petroleum, basic chemicals; 5) steel and other metal; 6) non-metallic, mineral products, and construction; and 7) other.

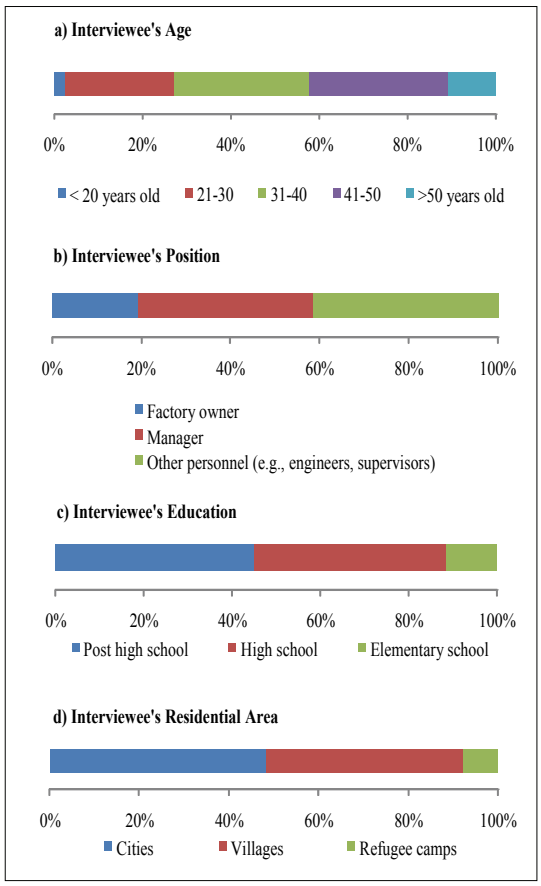

Fig. 2. Demographic distribution of interviewees in the governorates of Nablus and Ramallah & Al-Bireh, Palestine

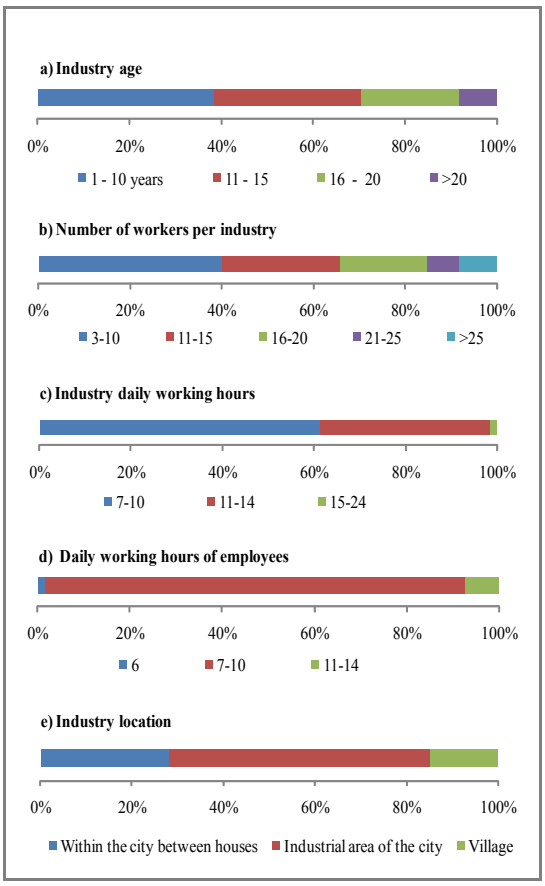

Fig. 3. General characteristics of surveyed industries in the governorates of Nablus and Ramallah & Al-Bireh, Palestine

An attempt was made in such a way that: i) the industry groups that produce relatively low density products are placed on the upper side, and of high density products on the lower side of the diagram; and ii) the industry groups producing products that are generally associated with food/ beverages, and agriculture/cilviculture are shown on the left side and other industries are on the right side of the diagram. Accordingly, the industry categories (1-3) are shown on the left side, and the categories (4-6) are on the right side. The percentage of the other industry category (7) is equally divided and placed on both sides at the bottom of the diagram.

Although available data are limited, it shows interesting features. In Nablus and Ramallah & Al-Bireh Governorates, the food and beverages manufacturing industries and agriculture sector comprise of 34% of the total industries and, the textile, fabrics and apparel industries 26%, and the oil, petroleum and basic chemicals industries 18% of the total industries.

In contrast, in Kuwait, the food and beverages manufacturing industries and agriculture sector comprise of only 7%, the highest percentage (46%) of the industrial activities belong to the textile, fabrics and clothing sector, and only 2% to the oil, petroleum and basic chemical sector (Alhumoud and Al-Kandari, 2008).

In Lebanon, the food and beverages manufacturing industries and agriculture sector comprise of 20%, which is between the Palestinian study site and Kuwait.

The availability of raw materials to industries on a continuous basis is essential for the Palestinian industries to sustain high productivity. Evidently, the availability of raw materials is lacking in the study area. Palestinian industries are highly dependent on the Israeli economy. In fact, 57.8% of the Palestinian industries depend solely on Israeli companies and the rest are dependent on Israeli and various other sources (Fig. 5).

There are complex and difficult socioeconomic problems associated with Israeli occupation, particularly, controlled/restricted import of energy and raw materials. Even under the difficult circumstances, industries in the private sectors are making profits using the flexibility of their small to medium size as an advantage when market conditions are favorable to them (Ministry of National Economy, 2004). As a result of large shifts in world economy, medium- and high-tech firms have been created.

Furthermore, the Industrial Free Zones and the promising investment laws have encouraged investors to establish new enterprises in high-tech fields (Ministry of National Economy, 2004). Concerning dependency of the industries on high technology and quality of employees, only 9.9% of the industries totally depend on high technology and 60.7% depend partially on high technology; 18.1% totally depend on highly qualified and well trained employees in the governorates studied (Fig. 5).

3.3. Sources and generation rates of industrial solid waste

In Nablus and Ramallah & Al-Bireh Governorates, only 12% industries produce significant quantities of non-process ISW: the remaining 88% of the industries primarily produce only process ISW.

The larger quantities of ISW are generated by basic chemical (2044.2 tonne/year), food and drink (1973.5 tonne/year), and pulp and paper (1807.0 tonne/year) industries. The rates of ISW generation are presented in terms of major industry categories in Table 1 and ISW component categories in Table 2.

The composition of waste reflects characteristics (e.g., densities, toxicity) of the waste; therefore, identifying waste composition is important in determining methods for effective recycling, reuse, treatment, and final disposal.

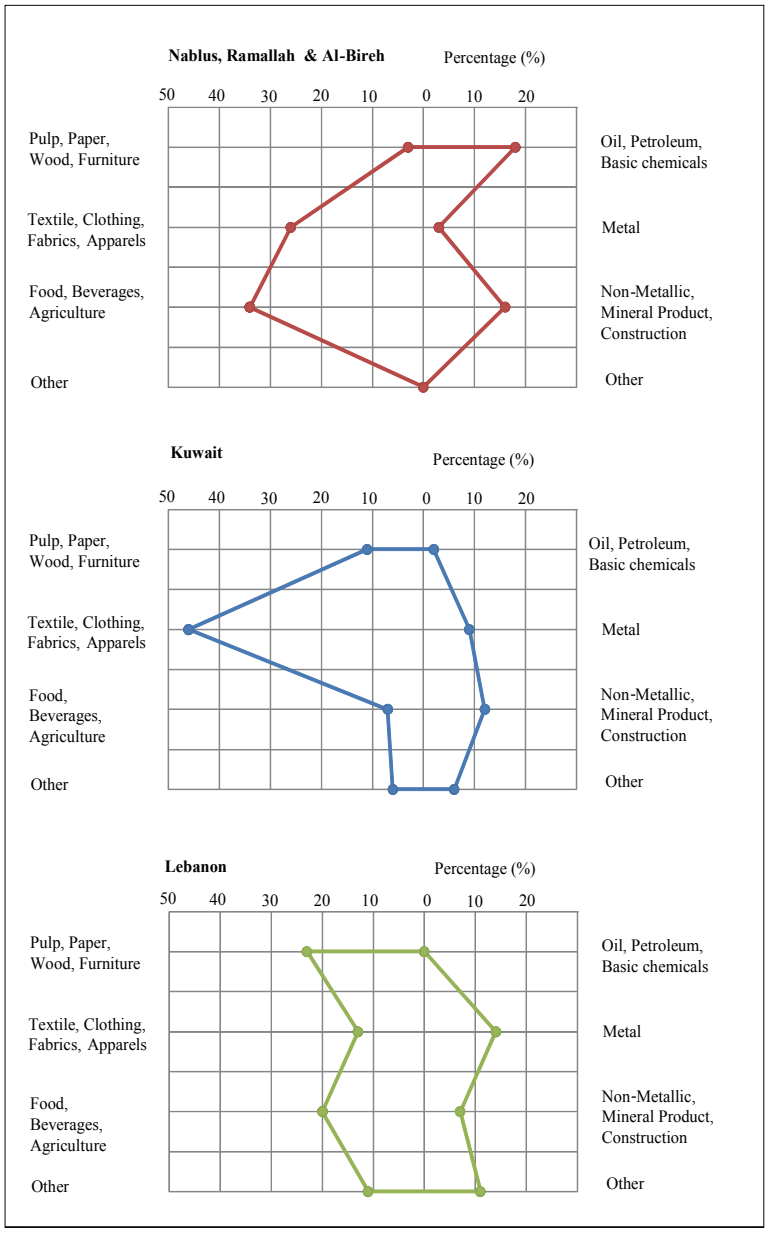

Fig. 4. Composition of industrial sector in the governorates of Nablus and Ramallah & Al-Bireh, Palestine in comparison with Kuwait and Lebanon

Table 1. ISW generation rates based on major industry categories in the governorates of Nablus and Ramallah & Al-Bireh, Palestine

Category of industry	*Total number of industries*	*ISW generation rate*				*Remarks*
		(tonne/yr)	*s.d.*	*kg/day per industry*	*s.d.*	
Food and drink manufacturing	171	1973.5	133.4	38.5	2.6	25.1% of total ISW; A large portion of this waste is plastics and cartons from packaging processes
Textile manufacturing	143	393.3	557.7	9.2	1.3	5.0% of total ISW; This category includes textile and clothing industries. Very limited reuse or recycle
Non-metallic products	86	772.4	57.6	32.2	2.4	9.8% of total ISW; Include rubber, plastics, and wood, furniture, glass and sponge products.
Pulp and paper products	17	1807.0	153.0	354.3	3.0	23.0% of total ISW; A large portion of this waste is reused or recycled. Some is sold to Israeli companies for recycling purposes
Basic metal manufacturing	18	791.3	756.0	146.5	1.4	10.1% of total ISW; Mainly metal scrap, most of it is sold to Israeli companies for recycling purposes
Basic chemicals manufacturing	98	2044.2	185.2	69.5	6.3	26.0% of total ISW; Expired chemical solids or vestiges of the manufacturing processes
Agro-industry	13	71.2	7.0	18.3	1.8	0.9% of total ISW; Waste from animal-feed and other agricultural industries

s.d., standard deviation

Table 2. ISW generation rates based on major waste components in the governorates of Nablus and Ramallah & Al-Bireh, Palestine

ISW generation rate			
ISW component	*(tonne/year)*	*s.d*	*% ISW component*
Papers and cartons	7252.5	105.9	47.7
Plastic	1112.3	65.6	7.3
Glass	86.8	8.4	0.6
Metals	3065.1	32.9	20.2
Remnants of plants	539.1	41.4	3.5
Sludge	125.4	9.5	0.8
Dust/soil	80.8	2.9	0.5
Sand	23.9	1.4	0.2
Rubber	54.0	2.4	0.4
Solid chemical waste	1231.7	81.5	8.1
Other wastes	1617.5	87.6	10.6
Total	15189.1	439.5	100.0

s.d., standard deviation

For the purpose of comparison of results from this study with others, ISW components are grouped into seven categories: 1) paper, cartons and wood; 2) wool, thread, glass, leather, insulation materials; 3) food and plant remnants; 4) plastic and other solid chemical waste; 5) steel and other metals, 6) construction and demolition waste, limestone, soil, sand, dust, and sludge; and 7) other waste.

Fig. 6 shows percentages of ISW component by weight, which was drawn based on the same concept used in developing the industry distribution diagram. That is, i) relatively low density wastes are placed on the upper side, and of high density wastes on the lower side of the diagram; and ii) the wastes that are generally associated with food/ beverages, and agriculture/cilviculture are shown on the left side and other wastes are on the right side of the diagram. Accordingly, the waste categories (1-3) are shown on the left side, and the categories (4-6) are on the right side.

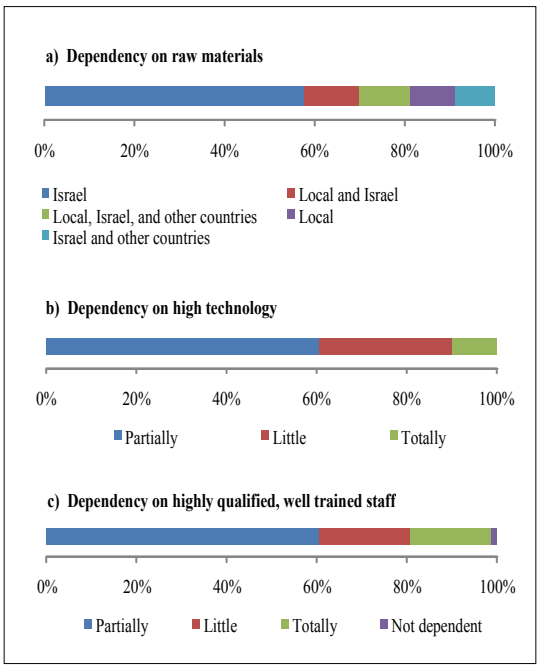

Fig. 5. Industry dependency on a) raw materials, b) high technology, c) highly qualified, well trained employees, in the governorates of Nablus and Ramallah & Al-Bireh, Palestine

The percentage of the other waste category (7) is equally divided and placed on both sides at the bottom of the diagram. From the diagram, it is clear that the largest percentage of ISW component by

weight is wood, papers and cartons, which make up 47.7% of the total ISW. It should be noted that the paper, pulp, wood and furniture industries comprise of only 3% of the total industries in the study area. Similarly, in Kuwait, the wood related industries comprise 11% of the total industries but produce a large amount of paper, cartons and wood waste, which makes up 35% of total ISW. It is noteworthy that paper and carton wastes are not only generated by pulp and paper industries but also by many other industries as packaging materials. The category of steel and metals makes up 20.2% of the ISW; of which 95.5% is from basic metal industries. One other major ISW component group is plastic and other solid chemical waste, which is mainly generated by basic chemical manufacturing industries, and makes up 15.4% total ISW. Plastic waste such as plastic containers and plastic sheets comprises 7.3% ISW; of which 31.76% is from non metallic industries, 18.35% from food and drink industries, and 19.99% from basic chemicals manufacturing industries. Plant remnants comprise 3.5% of the ISW mainly from food and drink manufacturing (36.44%) and agro-industry (21.56%). Sludge is 0.8% with the major sources from basic chemicals manufacturing (61.95%) and food and drinks manufacturing (24.87%). Glass is 0.6% with the main sources consisting of food and drink industries (32.33%), non-metallic industries (30.24%), and basic chemicals industries (27.67%). Rubber is 0.4% with the main sources of non metallic industry (58.75%) and food and drink manufacturing (34.7%).

Other ISW components include dust, soil, and sand, which are generated from nearly all types of industries. Percentages of the "plastic and solid chemical waste", "steel and other metals" and "construction and demolition waste" categories (on the right side of the diagram) in Nablus and Ramallah & Al-Bireh Governorates are similar to those in Tehran (Fig. 6).

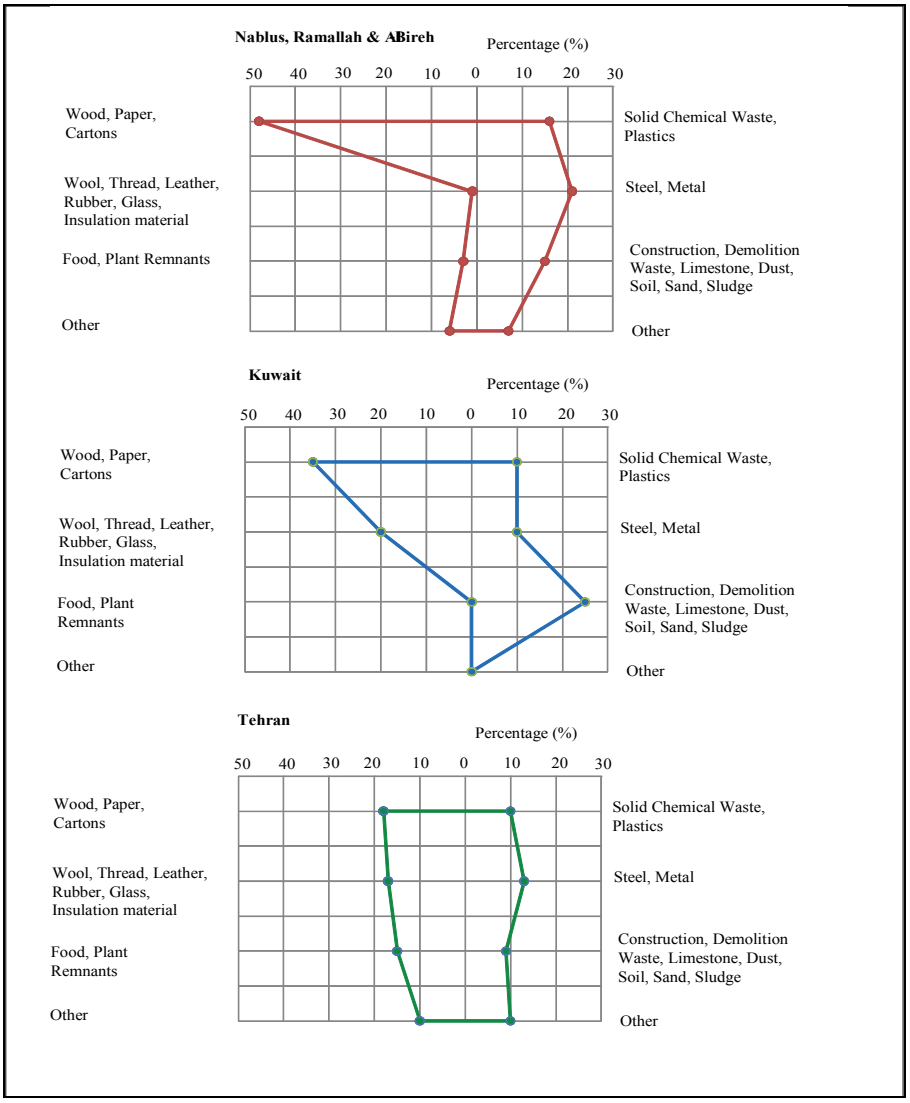

Fig. 6. ISW components in the governorates of Nablus, Ramallah & Al-Biren, Palestine in comparison with Kuwait and Tehran

3.4. Temporary storage facility and containers

The survey shows that, at almost all industries (99.5%), their workers clean industrial facilities, collect and store temporarily their waste in the containers. Metal and plastic containers are most commonly used for temporary storage, and account for 88.4% of all the storage facilities. Most of the containers are made of metal (95.4%), others are made of plastic (3.5%), and both metal and plastic (1.1%). 67.3% of the containers do not have covers, and the rest (32.7%) do.

The high percentage of lack of covers suggests poor supervision by municipality inspectors and absence of strict regulations that force the factory owners and managers to cover waste containers. Most (93.2%) of the containers are owned by municipalities or village councils, while only 6.8% are owned by industries. It is noteworthy that most of the containers used by the Palestinian industries are donated in the form of international aid: these containers can store large quantities of solid waste.

Percentage distribution of container capacities is shown in Fig. 7. The total capacity of containers used by industries ranges between 100 and 16,000 litres. The highest percentage (52.0%) of the industries are using a 2000-litre container or containers, and 53.5% are using two 2000-litre containers.

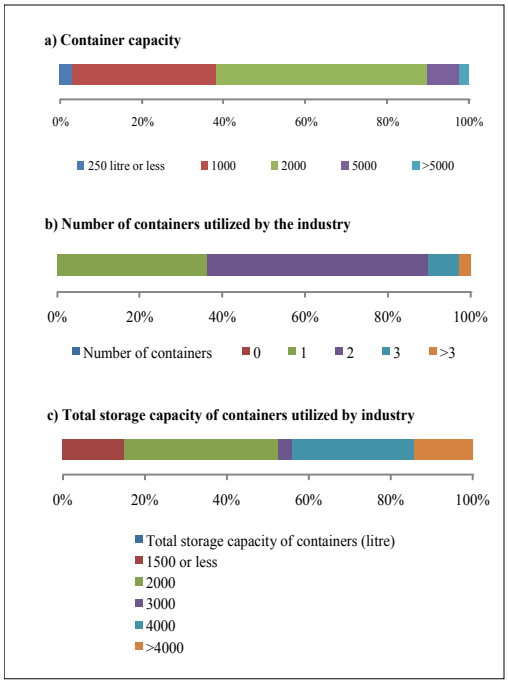

Fig. 7. Characteristics of containers used by industries in the governorates of Nablus and Ramallah & Al-Bireh, Palestine

In terms of the total storage capacity of containers, the largest percentage (37.8%) of the industries are using containers having a total capacity of 2000 litres and only 14.3% of the industries are using containers with the capacity larger than 4000 litres.

One of the important aspects of ISWM in developing countries is the lack of effective storage sites at the point of generation (Mrayyan and Hamdi, 2006). The lack of effective collection and storage systems is the source of many industrial waste problems. Therefore, the presence of effective storage and collection systems is the strong indicator for desirable ISWM systems.

In a general practice, ISW is first stored in a primary storage facility adjacent to its source. In Nablus and Ramallah & Al-Bireh Governorates, 62.2% of the industries have temporary storage places inside their facilities, while 38.8% have such places outside their facilities.

The size of ISW storage facility used for temporary storage at the source is generally proportional to the size of the industry, and depends on the types of the industry, rate of waste generation, waste collection frequency, and final disposal methods.

Open-air piling is practiced when there is a lack of containers, and also when industries are distant from their disposal sites and isolated from other industry areas. Open-air piles are generally located outside the industrial buildings and sometimes outside the properties of the respective industries. These waste piles are considered secondary storage facilities and become potential sources of environmental contamination. Waste that is stored in open piles in an open concrete room will not degrade easily even when it is exposed to rain water. However, filthy conditions may occur sometimes resulting from improper storage of ISW. Concrete rooms vary in sizes ranging from 2 to 8 m^3. Other storage methods include open-air piles (4% of the facilities), open concrete rooms (1.8%), covered concrete rooms (0.4%), both open-air piles and containers (3.3%), both containers and open concrete rooms (1.4%), and both containers and covered concrete rooms (0.7%).

In Tehran, plastic bags are mostly used to collect waste. According to Abduli (1996), about 36.7%, 22.4% and 12.4% of the industries use plastic bags, metal containers, and plastic containers, respectively, for the storage of their wastes, and 28.5% of the industries store their wastes inside their open areas. The containers used for storage are washed or disinfected by detergent or water in 28% of the industries, they are emptied once a day in 59%, once a week in 23%, twice a week in 7.7%, once every other week in 2.6%, and emptied once every other month in 7.7% of the industries. Collected wastes from different parts of the industries are stored in some areas inside the industry's yard, known as central storage point. Only 67% of the industries have central storage points. These storage points are cemented walls or simply possess a large capacity container that is easily accessible to waste

collection vehicles. Because of the poor collection system, with 28% of the industries, leachate problems were observed around the central storage points. The maintenance level of storage areas was medium or low in 41% of the industries (Abduli, 1996). In Corlu, Turkey, a curb side collection method is generally employed. Solid waste is stored in containers with different sizes ranging from 0.4 to 0.8m^3. There is a dearth of data on the number of containers being used in Corlu (Abduli, 1996).

3.5. Frequency of collection and transportation

The frequencies of collection and transportation of ISW from temporary storage places to final disposal sites were surveyed. In the study area, 55.1% of the industries collect and transport their waste twice a week, 39.4% do daily, and 5.5% do other than twice a week or daily. It was expected that ISW collection frequencies depend primarily on the industry type (i.e., nature of waste). Figure 8 shows the frequencies of ISW collection with respect to the types of industries in the governorate of Nablus and Ramallah & Al-Bireh.

The cross-tabulation between the types of industries and the frequencies of ISW collection shows that there is a statistically significant relationship between the industry types and the collection frequencies (chi-square = 45.02, df = 30, p-value = 0.038). The highest percentages of the industries that collect their ISW on a daily basis are food and drinks, pulp and paper products, agro-industries, and construction materials industries. Industries with high collection frequencies are typically characterized by either producing readily biodegradable waste, requiring high hygiene standards, or generating large quantities of waste on a continuous basis.

Other factors that affect the frequency of collection and transportation of ISW may include the size of industry, number of workers, waste generation rates, and means of transportation.

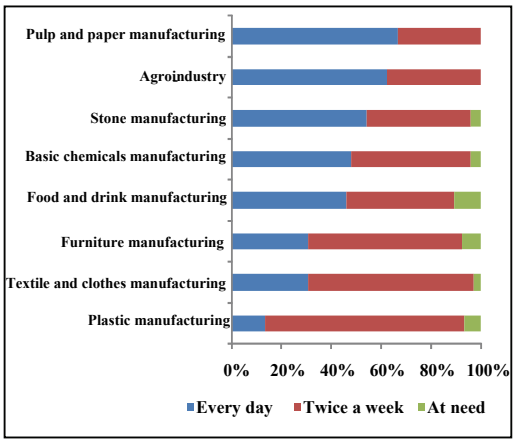

Fig. 8. ISW collection frequency in the governorates of Nablus and Ramallah & Al-Bireh, Palestine (chi-square = 45.02, df = 30, p-value = 0.038)

Decomposition of spoilable waste can be avoided by shortening storage time. If such waste is kept for a longer period, the storage site can quickly become an unsightly place and a public nuisance. The waste, once spoiled, produces not only offensive odors, but also attracts insects (e.g., flies, cockroaches) and rodents (e.g., mice, rats) which may transmit disease to humans. Thus, open dumps near ISW containers pose serious human health problems as insects and rodents frequently invade nearby dwellings. 15.2% of the interviewees replied that insects and rodents are "always present" in the temporary ISW storage area, and 64.5% replied "sometimes present", 40.8% responded that there are "always or sometimes complaints" about ISW from the people living nearby; 59.2% responded that there are "no complaints." It is probable that a lack of daily waste collection scheme is adversely affecting the environment and public health in the study area.

In the governorate of Nablus and Ramallah & Al-Bireh and other parts of the West Bank, ISW is collected mainly by two methods. The first method is the direct collection method in which waste-pickup vehicles collect waste using 1.1 m^3 waste containers or smaller size barrels. The second method utilizes skip-lift vehicles to collect ISW from skip-lift containers (5-6 m^3 or larger). Since there are no vehicles that are designed specially for ISW collection, the same vehicles that collect MSW are used to collect ISW. Two or three workers are generally assigned to each truck. Handcarts are usually handled by one or two workers. The survey shows that 56.7% of the interviewees are satisfied with the current collection systems.

In Tehran, 49% of industries use trucks to transport their wastes to the landfill, 33.3% use pickup trucks, 13.3% use rear-loaded collection vehicles, and 4.4% use both trucks and pickup trucks (Abduli, 1996). 34% of the industries use private sectors to collect and transport wastes, 21% of the industries use public services, and 45% of the industries collect and transport their wastes by themselves (Abduli, 1996). Substantial portions of ISW produced in Tehran are never collected. Uncollected ISW are thrown on any available piece of land or in ditches, or are blown away by the wind. In Zarqa, Jordan's industrial centre, trash collection trucks owned by the municipality pick up waste daily form metal dumpsters and transport the waste to its ultimate disposal site, i.e., Al-Russifa landfill (Mrayyan and Hamdi, 2006). The solid waste management system in Dubai is far advanced: the solid waste collected is segregated by professional technicians, and then transported to nearby solid waste facilities by vehicles equipped with the latest technologies (Al-Qaydi, 2006).

3.6. Segregation, treatment, recycling, and reuse

In Nablus and Ramallah & Al-Bireh Governorates, a small portion of ISW is being recycled in spite of the fact that a large proportion of

it can be either recycled or directly reused. Results of the survey concerning segregation, treatment, reuse, and recycling of ISW are presented in the Fig. 9.

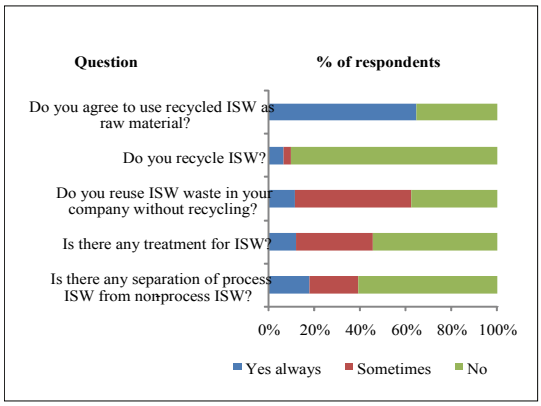

Fig. 9. Interviewees' responses concerning separation, treatment, reuse, and recycling of ISW in the governorates of Nablus and Ramallah & Al-Bireh, Palestine

3.6.1. Segregation and treatment

In the governorates studied, only 18.1% of the industries "always" segregate process ISW from non-process ISW, while 60.6% do not segregate ISW and 21.3% sometimes segregate ISW. 56.7% industries do not segregate their wastes into specific components, while 32.4% of industries always segregate it near their sources, and 10.9% do it sometimes. During the survey interview, industries that do not segregate their wastes were asked whether or not they were willing to segregate their wastes if necessary infrastructure to segregate their waste was provided: 58.2% are willing to segregate their wastes; 41.8% are not.

The reasons for unwillingness to segregate waste are probably because there are little incentives; for example, no economic values with recovered waste, limited number of workforce, and excess amount of time consumed. The major waste materials that can be recycled in the studied region are paper and cartons, plastic, glass, metals, and rubber. Pharmaceutical, plastic, furniture, food, concrete, and metal industries generally separate or partly separate their waste into reusable components.

Simple treatment of ISW can yield benefits to industries in terms of its recycling, reuse, and/or final disposal. Such treatments include cleaning, compacting, and crushing. Bulk items can be compacted manually or mechanically to reduce their volume or crushed into small pieces prior to be used as raw materials. The survey showed that the large percentage (54.2%) of the industries do not treat their waste: only 12.1% do treat it.

In Nablus Governorate, the municipality has constructed the Al-Sayrafi transfer station in cooperation with a private sector. In the facility, there is a recycling pilot plant where a mechanical separator is used to segregate recyclable and reusable materials. Solid wastes including ISW generated in the city of Nablus and other localities, are collected and transported to the transfer station where solid waste is segregated into cartons, plastic, and metals.

An organic fraction of the solid waste is also recycled. Currently, the station receives about 150 tonne/day: percentage of segregated waste is 15 to 20%. From the station, remaining solid waste is transported to the Zahrat Al-Finjan sanitary landfill by trailers.

3.6.2. Reuse and recycling

In the governorates studied, the main materials that are being reused and/or recycled are plastic, wood, papers, and metals. The survey shows that 11.6% of the industries "always" and 50.7% "sometimes" reuse their solid waste without recycling, and that only 6.6% "always" and 3.3% "sometimes" recycle their solid waste.

Industries that recycle their solid waste utilize it in different ways: 25.9% of the industries use it as raw materials, 48.1% use it by mixing it with raw materials, and 25.9% sell it to other companies. 64.7% of the interviewees agree that industries should use recycled waste as raw materials, while 35.3% do not agree to it.

3.6.3. Scavenging

In Palestinian governorates, the quantities of ISW reuse and recycling are not documented since the reuse and recycling activities are largely carried out by scavengers (waste pickers). Scavengers pick useful materials from ISW dumps, and sell them for reuse or recycling, or keep them for their own use. In this study, 49.0% of the interviewees replied that they had "always" noticed scavengers picking waste from ISW storage containers, 28.0% had "sometimes" noticed, and 23.0% had not noticed. Due to severe shortages of employment opportunities in the Palestinian society, recovery of useful materials from ISW storage sites has become an important survival strategy in a disadvantaged population.

Medina (1997) says, "when scavenging is supported, it represents a perfect illustration of sustainable development that can be achieved in the Third World: jobs are created, poverty is reduced, raw material costs for industries are lowered (while improving competitiveness), resources are conserved, pollution is reduced, and the environment is protected."

In this survey, only 1.4% of the interviewees consider ISW "very dangerous" to the environment and human health; 49.8% consider it "dangerous"; 40.8% "somewhat to a little dangerous"; and 8.0% "not dangerous."

3.7. Final disposal

Percent distribution of the industries surveyed on final ISW disposal methods is shown in Fig. 10.

Results show that 68.8% ISW is currently disposed of at either landfills or municipal dumpsites; the remaining is disposed of at either private

dumpsite or on-site, randomly disposed of, or uncounted. This contributes to the increase of landfilled waste (Sasao, 2014).

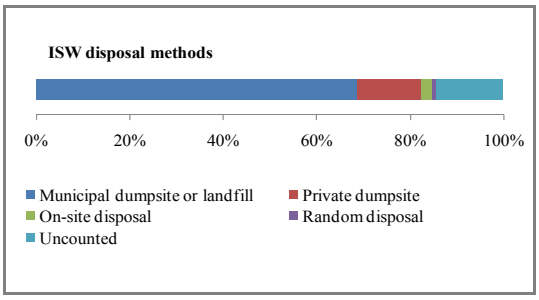

Fig. 10. ISW disposal methods in the governorates of Nablus and Ramallah & Al-Bireh, Palestine

Industries in Nablus Governorate dispose of their solid waste in the Zahrat Al-Finjan sanitary landfill, which receives mixed (municipal and industrial) solid waste (Al Sa'di, 2009). On the other hand, industries in Ramallah & Al-Bireh Governorate dispose of most of their solid waste at dumpsites; most of which are located within the same governorate. The Ramallah dumpsite, when originally created in the late 1960s, had an area of about 4500 m^2.

This dumpsite has received and is receiving all types of solid wastes from the Ramallah and Beituniya municipalities. Today, waste is mounting dangerously near the industrial zone. The waste pile has reached more than 60 meters high, posing a risk of a collapse of the waste pile over nearby residential housing and industrial facilities, especially during winter when the pile is wet and unstable (Al-Khatib and Abu Safieh, 2003). Furthermore, leachate from the dumpsite becomes a potential source of soil and groundwater contamination (Kaseva and Mbuligwe, 2000). Since 1981, the Al-Bireh municipality, adjacent to Ramallah, has had its own dumpsite outside the municipality boundaries. This unsanitary dumpsite is receiving various types of solid wastes including both MSW and ISW (Al-Khatib and Abu Safieh, 2003).

3.8. Integrated ISWM system

The ISWM problems include rapid and extensive urban development, presence of many industries in the urban areas, and limited funding to public services. In Palestine and many other countries, productivity is of primary importance to industries, and consumption of natural resources, generation of waste and potential impacts on the environment are not major considerations in overall planning and design of manufacturing processes. What is urgently needed to protect the environment and public health are the establishment of an effective ISWM program, and promulgation of ISW laws and regulations (Batool and Ch, 2009; Bhatnagar and Jain, 2005; Olanrewaju and Ilemobade, 2009; Sharholy et al., 2008). In Palestine, Joint Councils for Services, Planning and Development (JCSPD) are responsible for creating a robust institutional framework, reducing waste management costs, supporting sustainable development of communities, improving environmental and human health conditions, and raising the quality and efficiency of public services in the rural areas (Al-Khatib et al., 2010; Ministry of Local Government, 2004).

The most important role of JCSPD is to establish Joint Councils for solid waste management in each governorate, proceeding with environmental services such as closing all random dumpsites and developing a sanitary landfill in each governorate. Municipalities are members of the joint councils, and their main role is to collect solid waste within their boundaries, and transport it to a sanitary landfill if available. The Ministry of Local Government (MoLG) in coordination with the EQA develops laws and regulations that support JCSPD's vision.

3.8.1. Cleaner Production Principle

The United Nations Environment Programme (UNEP) introduced the "cleaner production (CP)" principle in 1990 (UNEP, 2010). CP is defined as "the continuous application of an integrated environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment."

In a production level, raw materials and energy should be conserved, toxic materials should be eliminated, quantity and toxicity and all pollutant emissions should be reduced. In a product level, the CP principle is expected to produce results that reduce negative impacts throughout the life cycle of a product (from selection of its raw materials to ultimate disposal) (Miró et al., 2015). In a service level, the CP integrates environmental concerns into the designing of products and required services. Overall, the CP requires evaluation of technology options, changing attitudes in all stages of production, delivery of products, and services, and responsible environmental management (Tasmania Government, 2010; Ujor et al., 2014).

The authors believe that the CP concept is important in all aspects of the industrial processes, and that the concept needs to be implemented among industrial sectors. Responsible organizations should conduct public awareness campaigns for the CP principle as it is not known to many industry owners and managers. A survey shows that only 31.8% interviewees heard about the CP concepts and 68.2% did not hear about it. If ISW is managed properly, there will be a positive impact on the total productivity of industries, and the quality of human life and the environment. This study shows that high percentages of ISW are recyclable and/or reusable materials. Recycling and reuse provide at least a part of the solutions to the ISW problems, and should be considered in future plans for sustainable development of the Palestinian communities.

Important aspects that should be taken into consideration include a comprehensive regulatory framework, technical support, improvement on operation and management, and economic incentives. Industrial sectors should be educated so that they will realize that: *i*) ISW generated in manufacturing processes is as important as products; *ii*) ISW should be minimized through waste reduction and recovery at source, and *iii*) recycling and reuse of ISW can minimize adverse environmental and human health impacts. Successful recycling and reuse of ISW can be achieved via an in-depth understanding of the CP principles, integrating environmental and public health considerations into community planning and development. Moreover, safety and health plans should be developed for all ISW processing and disposal facilities, including operational guidelines for waste handling and emergency first aid procedures.

An acceptable level of occupational safety should be maintained in accordance with the standard requirements. For example, protective equipment and clothes should be available for all handling workers. There should be clear policy for vaccination against infective diseases and medical examinations either before or during employment. Supervisors should pay attention to their workers' occupational safety and satisfaction. All employment benefits (e.g., job security and satisfaction, occupational safety) should be made available to waste handling workers in order to help them perform their work properly. Workers should be trained for handling of hazardous wastes. It should be noted that the hazardous waste aspects lie outside the scope of this paper.

The issues associated with medical solid wastes in the West Bank, Palestine were addressed by Al-Khatib and Sato (2009). The necessary measures in dealing with hazardous solid wastes can be found in Europe Council Directive (2010).

3.8.2. Industrial symbiosis

Industrial symbiosis (IS) has emerged as a self-organizing business strategy among the firms that are willing to cooperate to improve their economic and environmental performance. The adoption of such cooperative strategies generally results in increases in costs of waste management since most of which are driven by policy and legislative requirements. Development of IS depends on an enabling context of social, informational, technological, economical and political factors. The power to influence this context varies among the entities such as the government, businesses, or coordinating entities. Governmental intervention, as manifested through policies, could influence a wider range of factors being studied (Costa et al., 2010).

To date, little evidence exists, which may help regulators understand why some firms comply environmental regulations even when there is little financial incentive to them, while others continuously violate the same regulations. The probability of having compliance depends, among other factors, on the types of management practices and the level of environmental training. Some firms in the manufacturing sector may have been over-complying with regulations. It has been shown that providing environmental training to employees increases the probability of over-compliance. Local communities may have positive impacts on over-compliance; however, the magnitude of their impacts is not so strong as is often suggested in the literature (Gangadharan, 2006).

Since the CP principle was formally brought forward by the UNEP/PAC in 1989, it has become a part of sustainable development strategy, and has been adopted by various social sectors and municipalities in many countries (Liu et al., 2011). The importance of developing diverse ecological production systems and of promoting economy based on recycling has been recognized. And the promotion of the CP principle and acceleration of the ecological industrial systems has been acknowledged as one of the key strategies. If the CP practices becomes more diverse, the assessment studies that include cities, industries and enterprises will gradually grow (Howgrave-Graham and Berkel, 2007; Xinshan et al., 2007).

4. Conclusions and recommendations

This study presents survey results on current ISWM practices in the governorates of Nablus and Ramallah & Al-Bireh in the West Bank, the Palestinian territory. Solid waste generated from industries was quantified and characterized in terms of generation, storage, collection, transportation, processing, and final disposal of ISW.

The specific findings are as follows:

- The quantities of ISW in an order of the largest generator are 2044.2 tonne/year by basic chemical industries, 1973.5 tonne/year by food and drink industries, and 1807.0 tonne/year by pulp and paper industries.
- The highest percentage (47.7%) of the ISW components is paper and cartons, which amounts to 7252.5 tonne/year.
- The paper, pulp, wood, and furniture industries that comprise only 3% of total industries produce 47.7% of the total ISW.
- 68.8% of the total ISW generated is disposed of at either dumpsites or landfills.
- 39.4% industries transport their waste to final disposal sites on a daily basis.
- 88.4% industries store ISW temporarily in containers owned mostly by municipalities and village councils.
- Metal (95.4%) and plastic (3.5%) containers are most commonly used for temporary storage; however, 67.3% of the containers do not have covers.
- 32.4% industries do segregate their wastes into different components, near the sources.
- The main waste materials that are being reused and/or recycled are plastic, wood, paper, and metals.

• 11.6% industries "always" and 50.7% "sometimes" directly reuse their solid waste.

• 25.9% industries use recycled material as raw materials, 48.1% use it by mixing it with raw materials, and 25.9% sell it to other companies.

To minimize public health and environmental impacts, hazardous waste landfills (e.g., specially designed burial cells constructed in the Zahrat Al-Finjan landfill site) should be used. Moreover, it is necessary to develop plans to remediate uncontrolled dumpsites. Responsible organizations including the EQA, MoNE, and MoLG, in coordination with the Palestinian Federation of Industries, should conduct public awareness campaigns to send messages about their missions and roles in improving ISWM systems to industrial sectors, local councils, and local communities. Furthermore, the authors recommend the following for future improvement and changes in the ISWM:

• Maximizing recycling quantity and minimizing landfilling quantity of ISW should be emphasized through the implementation of the "cleaner production" principle introduced by the UNEP in all industries in the Palestinian territory.

• The EQA should encourage industries to recycle and reuse their waste by disseminating information about recyclable and reusable waste types: i.e., scrap iron, scrap paper, wood, waste glass, spent bleaching earth, ceramic, brick, tile, casting sand, metals (e.g. iron and aluminum), and plastic.

• The EQA, in coordination with the MoNE, the Palestinian Federation of Industries, and Palestinian universities, should develop and publicize general ISW reuse types and procedures to promote waste recycling and reuse.

Efforts should be made to simplify and streamline official application procedures and approval processes to speed-up reuse and recycling of ISW.

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