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Field Study on Plastic Recycling in Alexandria City: Case Study in Montazah District

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Abstract: Recycling is an important factor in helping to reduce the demand on resources and the amount of waste. This work aims to study the pathway of plastic wastes in domestic solid waste [DSW], estimation of the generation rates of DSW and its total plastic [TP] Components, salvable plastic [SP], and finally optimizing the recycling of plastic. The DSW from 200 apartments from each level in Montazah district were collected. The field survey included a visit to four plastic industrial enterprises. The processing units were studied from the time of receiving plastic wastes until prepared for marketing . Almost all the mean weights of DSW increase as the standard level increases. The generation rate of DSW in all levels in Winter was greater than that of Summer. The annual generation rate of DSW is 427 /g/c/day. During Winter, the highest mean weights of TP& SP/c/day were recorded for high level. The generation rates of TP & SP in high and low levels in Summer were greater than that in Winter. In Summer and Winter, the middle level generated the highest percentage of TP & SP while the low level generated the least. The annual generation rates of TP & SP are 4.5 & 3.2 g/c/day. It has been found that SP & Rejected Plastics [RP] represent 72% and 28% of TP respectively. Polyethylene [PE] and Polystyrene [PS] represent 59.3% & 14.9% of TP. On the other hand, PE constitutes 77% of SP and PS represents 66.7% of RP. The highest percentage of PS in RP during Summer was recorded for the low level and the least percentage was recorded for the high level. While, during winter, the highest percentage was recorded for the low level and the middle level generated the least. Winter percentage of PE in SP and PS in RP are higher than that of Summer. In Summer and Winter, the highest percentage of PE was recorded for the middle level. During the survey of the four industrial enterprises, it has been found that the current methods of processing recycled plastics include many environmental problems especially air & wastewater pollution, and safety of workers which required correction. For optimization of plastic recycling, it has been recommended to implement minimization of plastic waste and /or recycling programs.

Keywords:
domestic solid waste, plastic recycling , generation rate, salvable and rejected plastics .

INTRODUCTION

Plastics are high molecular weight polymers. They are grouped into two categories: thermoplastics and thermosets. When thermoplastic materials are molded, they do not change chemically, and may be reheated and reformed. This means that plastic scraps can be used and

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consequently waste may be eliminated .[1] Plastics are now becoming accepted as raw materials available to industry, thus waste is generated and is being dealt with by known technology. There is no lack of technology to prepare thermoplastics waste for recovery, the two problems are [a] segregation and collection, and [b] a market for the product .[2] Global consumption of plastic resins was projected to increase nearly 4% annually from 101 million metric tons in 1983 to 123 million metric tons in 1998.[3]

People throw away solid waste without thinking about resources they are wasting or the environmental damage they are causing by producing so mush solid waste.[4] Consumer waste of domestic and trade origin constitutes the largest amount of plastic waste, with up to 90% being discarded packaging, predominantly thermoplastic in nature.[5] The recycling of plastics waste can not really be discussed outside the sphere of solid waste management.[2] Since the majority of plastic in refuse is thermoplastics, the decomposition products (with the exception of hydrogen chloride) are hydrocarbons in nature, which possess a high fuel value, thus plastic can make a welcome contribution to the calorific value of the waste. As a result of the advanced technology which has significantly imporved the quality and performance of plastic materials, their structure has been designed to offer a high degree of resistance to degradation, together with much improved physical properties. This has resulted in accumulations of plastic wastes which are difficult to dispose off by conventional techniques.[5]

There are basically three ways for handling plastic waste: disposal, reuse, and recycling.[6] Discarded plastics if not recycled will be disposed off by landfilling or incineration. All of these methods will affect the environment if they will not be managed correctly.

As the cost of raw materials increases, more manufacturers are attempting to economize by introducing a low level of external material from other sources into their product.[5] Thus recycling which could take any of three forms: a) internal receycling, b) Post-consumer scrap or external recycling, and c) tertiary recycling or thermal recycling6 is an important issue to reduce amount of

waste delivered to open dumping, to conserve irreplaceable natural sources, and to protect the environment.[7]

This study aims to study the pathway of plastic wastes in domestic solid waste (DSW) in Montazah district, Alexandria. It also will estimate the generation rates of DSW and its total plastic components. It will attempt to optimize the recycling of plastics from the consumers to the reprocessing enterprises.

MATERIAL AND METHODS

Montazah district which is located in the eastern part of Alexandria has been chosen to be the area of study because curbside collection is still available. The study was carried out during Summer 1995 and Winter 1996. The DSW samples were collected six days a week from each level. Eighteen samples were collected from each level in each season. From each area, samples were selected randomly. The DSW from 200 apatments from each level was collected. The collected DSW sample from each apartment was weighed, plastic components were segregated into salvable and rejected plastics. Three physical analyses in each season for each level were performed on commingled salvable plastics and rejected plastics. Determination of specific gravity for DSW and for plastics, and generation rates of DSW and plastics were determined. Generation rates of DSW and plastics were calculated as g/c/day. They field survey included a visit to four plastic industrial enterprises. The processing units were studied from the time of receiving plastic wastes until prepared for marketing.

RESULTS AND DISCUSSION

The current methods of solid waste collection in montazah district:

The Winter crew for collecting solid waste was seven for the three standard levels, while the Summer crew was one worker for both the middle and low levels, but five workers for the high level. Types of vehicles in Montazah district varied from the animal-drawn cart to the compaction truck. Inspite of the curbside collection in part of Montazah district, tons of refuse are not collected but build up on the streets.

Collection is carried out by door-to-door and curbside services. The refuse is

delivered to the truck-trailer where sorters arrange the refuse bags. The different types of salvable materials are segregated at different stages, by householders and the servants, by Zabbalin at the stairs of the buildings, on the truck-trailer, and finally at the dump site.

Generation rate of solid waste:

The results of seasonal and annual mean values for the collected DSW from high, middle, and low levels, during summer and winter seasons are presented in table [I] and Fig.[1]. It is shown that the generation rates of gm DSW /c/day increase as we go up the standard level.

It is clear from the table that in Summer and Winter seasons, significant differences were detected between mean weights DSW/c/day collected from high, middle, and low levels. It is clear that, during summer, the highest mean weights of DSW/c/day were recorded for the high level, [940 g/c/day]. On the other hand, the low level generated the least amount of DSW, [271 g/c/day].

There are very highly significant differences between the mean weights of

Table 1: Daily mean & standard deviation of generated gm of Domestic Solid Waste per capita in summer and winter according to atandard of living at Montazah District, Alexandria, (1995-1996)

Season / Standard of living	Summer		Winter		Annual	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
High	940	174	942	177	941	173
Middle	475a	79	614a	41	545	94
Low	271a	42	326a	34	299	46
Xw	384	63	469	44	427	71
ANOVA						
Significance	XXX		XXX		XXX	
LSD 5%	76		72		55	
LSD 1%	101		95		72	

Table 2: Daily mean & standard deviation of generated gm of Total Plastic & Salvable plastic per capita [g/c] in summer and winter according to standard of living at Montazah District, Alexandria. [1995-1996]

Season		Summer				Winter				Annual			
Standard of living	Plastic	g/c		% in SW		g/c		% in SW		g/c		% in SW	
		X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
	TP	11.5	2.8	1.23	0.27	10.4	3.5	1.14	0.43	11.0	3.2	1.19	0.36
High	SP	7.2	2.1	0.78	0.24	6.9	2.7	0.75	0.29	7	2.4	0.76	0.26
	TP	6.3a	1.0	1.35	0.31	7.4a	1.5	1.2	0.23	6.8	1.4	1.28	0.28
Middle	SP	4.4a	1.0	0.95	0.23	5.2a	1.4	0.86	0.21	4.8	1.2	0.9	0.22
	TP	2.7a	0.5	1.01	0.23	2.1a	0.4	0.65	0.14	2.4	0.5	0.83	0.26
Low	SP	1.9a	0.3	0.73	0.15	1.6a	0.4	0.49	0.15	1.8	0.4	0.61	0.19
	Xw	4.5	0.8	1.16a	0.26	4.6	1	0.89a	0.19	4.5	1	1.02	0.27
TP	ANOVA	***		**		***		***		***		***	
	LSD5%	1.2		0.18		1.5		0.2		0.9		0.15	
	LSD1%	1.5		0.24		2.5		0.26		1.3		0.2	
	Xw	3.2	0.7	0.82a	0.18	3.3	0.9	0.65a	0.18	3.2	0.8	0.73	0.21
SP	ANOVA	***		**		***		***		***		***	
	LSD5%	0.9		0.14		1.2		0.15		0.7		0.15	
	LSD1%	1.2		0.19		1.6		0.2		1		0.2	

X = Arithmatic mean
Xw = Weighted arithmatic mean
SD = Standard deviation
LSD 5% = Least Significant Difference at $p<0.05$
LSD1% = Least Significant Difference at $p<0.01$
a= figures having this letter are significantly different

TP= Total plastic
SP = Salvable plastic
SW = Solid Waste

Table 3: Annual and seasonal percentage of polyethylene [PE] and other resins in salvable plastic in the three standards at Montazah District, Alexandria, (1995-1996)

Season		Summer		Winter		Annual	
Standard of living	Plastic	X	SD	X	SD	X	SD
	PE	48.9	15.4	77.2	21.4	63.1	22.8
High	Others	51.1	15.4	22.8	21.4	36.9	22.8
	PE	81.4	10.2	84.1	4.5	82.7	7.2
Middle	Others	18.6	10.2	15.9	4.5	17.3	7.2
	PE	73.9	3.9	74.5	1.9	74.2	2.7
Low	Others	26.1	3.9	25.5	1.9	25.8	2.7
	Xw	75.6	6.9	78.4	3.9	77	5.5
PE	ANOVA	*					
	LSD5%	21.75					
	LSD1%	27.94					
	$\bar{X}w$	24.4	6.9	21.6	3.9	23	5.5
Others	ANOVA	*					
	LSD5%	21.75					
	LSD1%	27.94					

Others include Polypropylene , Poly Vinyl Chloride, and certain Poly Ethylene containers

Table 4: Annual and seasonal percentage of polyethylene [PS] and other resins in rejected plastics in the three standards of living at Montazah District, Alexandria, (1995-1996)

Standard of living	Plastic	Summer $\bar{X}$	Summer SD	Winter $\bar{X}$	Winter SD	Annual $\bar{X}$	Annual SD
	PE	43.1a	6.4	65.2a	4.7	54.1	13.1
High	Others	56.9a	6.4	34.8a	4.7	45.9	13.1
	PE	64.5	4.5	60.6	13.6	62.5	9.3
Middle	Others	35.5	4.5	39.4	13.6	37.5	9.3
	PE	65.8	9.8	75.6	12.6	70.7	11.4
Low	Others	34.2	9.8	24.4	12.6	29.3	11.4
	$\bar{X}w$	64.1	7.6	69.2	12.6	66.7	10.7
PE	ANOVA	*					
	LSD5%	14.47					
	LSD1%	18.58					
	$\bar{X}w$	35.9	7.6	30.8	12.6	33.3	10.7
Others	ANOVA	*					
	LSD5%	14.47					
	LSD1%	18.58					

Others include Polyethylene Terephthalate [PET] and Poly Vinyl Chloride [PVC]
a= Figures having similar letters are significantly different

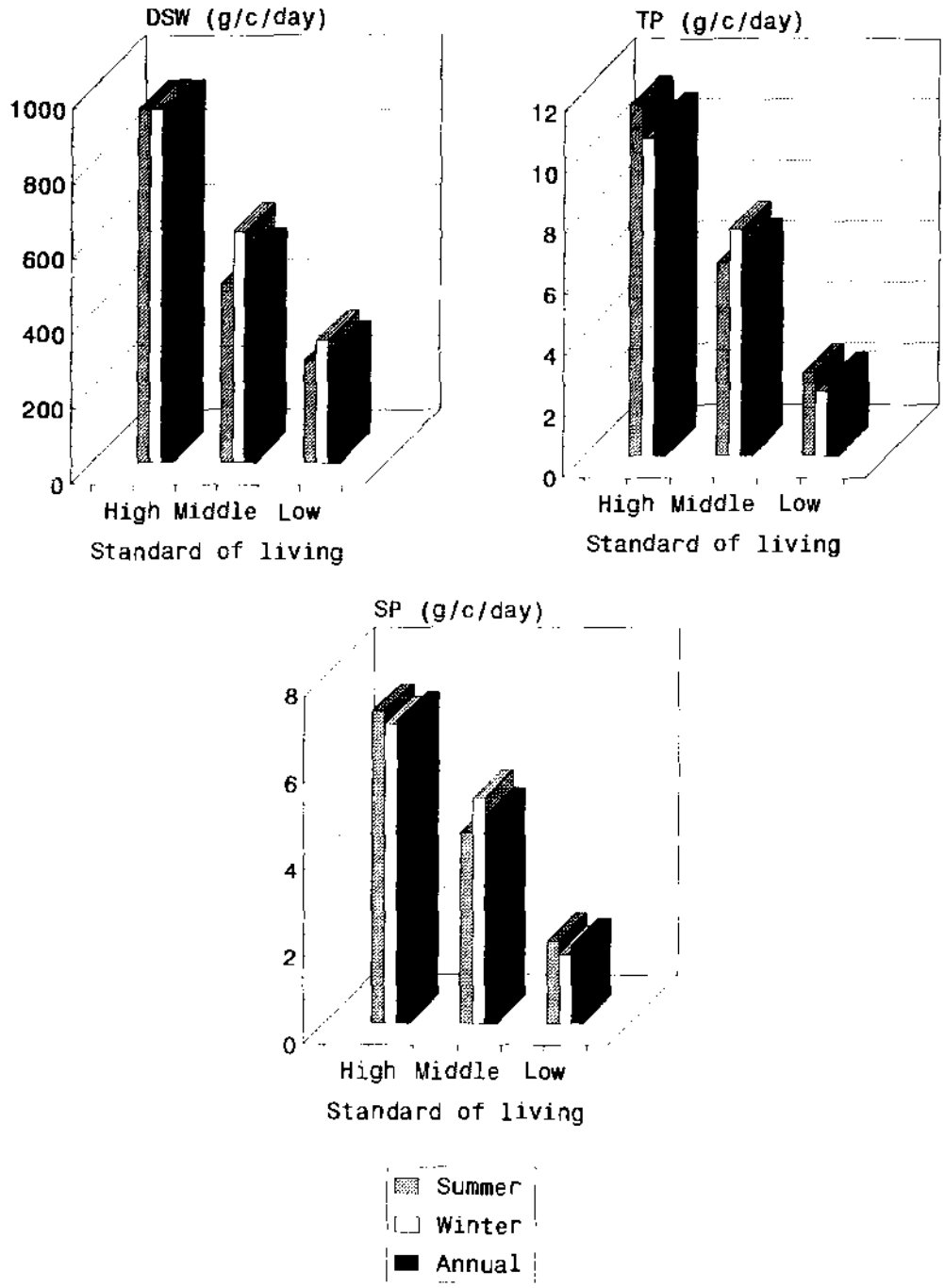

Figure 1: Seasonal and annual mean of generated gm of Domestic Solid Waste [DSW], Total Plastic, and Salvable Plastic [SP] according to the standard of living at Montazah District, Alexandria, [1995-1996]

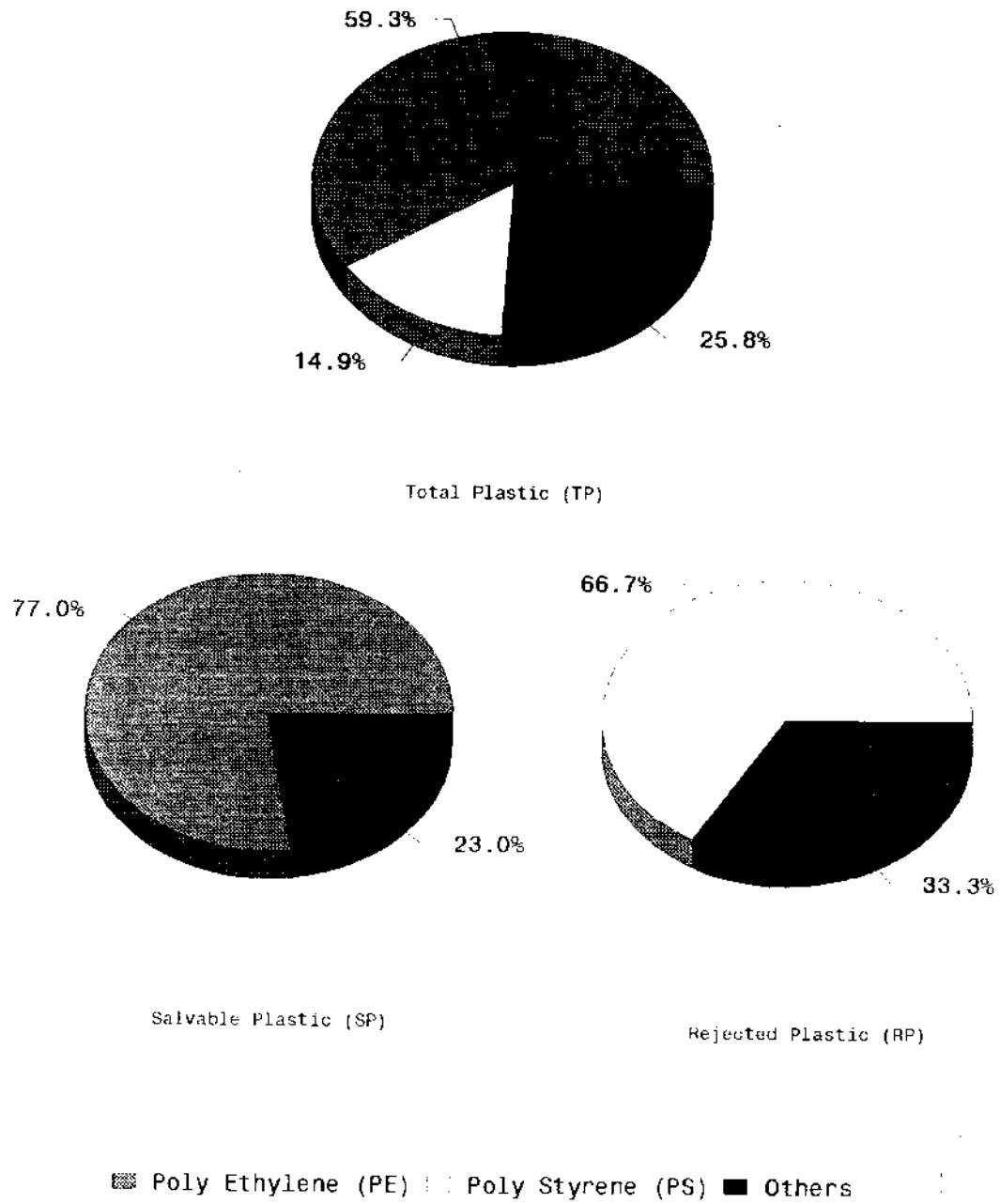

Figure 2: Percentage of polyethylene [PE] and polystyrene [PS] in total plastic [TP], salvable plastic [SP], and rejected plastic [RP]

DSW/c/day between Summer and Winter in the middle and low standard levels. It has also been found that in Summer and Winter, the high level generated the highest mean weight, for it discards almost all of its wastes, e.g., even furniture [old chairs], old pieces of carpet,..., etc. On the other hand, the the low standard level population generated the lowest mean weights as they used their garbage as food for their poultry, sheep, dogs, and donkeys.

If these results are compared with the previous studies done in Alexandria ,[8,9,10] it would reveal that the weighted arithmetic mean in Winter of 1979[257g/c/day] was lower than that in Summer [293g/c/day], while the reverse was true in 1995-1996[469 and 384 g/c/day, respectively]. For annual generation rate, it has been found that from 1979 to 1994 high and middle standard level it was at its maximum in 1981-1992[310 g/c/day]. However, in 1994[500 g/c/day] it was more than that of 1996[427 g/c/day]. It is expected that the annual generation rate of 1994 lies in between the 350 g of 1981-1982 and 427 g of 1996. Nevertheless, this was not valid. This may be attributed to that the 500 g/c/day in 1994 study was an extrapolated value, while that of 1996 was an actual field-based value. It is also clear that the generation rate in all levels in Winter is greater than that of Summer because it is expected that people go to the beach in Summer, where they stay all the day. It has been found that the generation rates of volumes of DSW from the three standard levels of the present study in Alexandria [13.373 liters/apartment/day] nearly doubled since 1979[8.4 liters/apartmennnt/day].

In a comparison between the annual generation rate in some of the Egyptian cities[11,11,13][290,650,460 g/c/day respectively] and the results of the present study, it has been found that the generation rates for almost all of them were within the range of the present study. The annual generation rate of the present study is low as compared with that of some of the Arab cities [14,15] [800& 950 g/c/day respectively] and the developed foreign countries[16] [from 832 to 2388 g/c/day] but higher than that of the less developing countries [17] [150 g/c/day].

Generation rates of total plastics and its components:

The seasonal and annual mean values of generation rates and percentages for the collected plastic waste from high, middle, and low levels during summer and winter seasons are presented in table [2] and fig [1].

It is clear from the table that during Summer season, very highly significant differences were detected between mean weights of generated total plastic [TP] & salvable plastic [SP] from high, middle, and low standard levels. The differences in weights of TP/c/day and SP/c/day were manifested between high level and both middle and low levels, and between middle and low levels. This can be attributed to that SP is kept by the servants of the high standard level, while the low standard residents sell their own SP. Therefore, middle level SP% [0.95%] is higher than that of both other levels.

In Winter, a very highly significant difference was detected between mean weights of TP&SP collected from high, middle, and low standard levels. The difference was manifested between high level and both middle and low levels and between middle and low levels in weights of TP/c/day and SP/c/day. It is clear that during Winter, the highest mean weights of TP/c/day and SP/c/day were recorded for the high level [10.4 g/c/d for TP and 6.9 g/c/day for SP] while the low level generated thes least [2.1 g/c/d for TP and 1.6 g/c/d for SP]. Very highly significant difference were detected between high, middle , and low standard levels regarding the percentage of TP & SP. The differences in TP & SP were manifested between low and middle levels.

There were significant differences between Summer and Winter regarding the mean weights of TP&SP in the middle and low levels. This can be attributed to that, among the low level, SP were sorted out and sold by the low level population . It is greater than that in Winter, while the generation rates of TP&SP in middle level in Winter were greater than that in Summer. This can be attributed to that population of this level spent most of the day at beach side during Summer. There were significant differences between seasons for percentages of TP&SP in the low level only. This can be attributed to

the consumptiomn of more packaged-food in Summer than in Winter, especially by children. It is clear from the table that the percentages of TP& SP discarded in Summer were significantly higher than that in Winter in all levels.

It is clear from the table also that very highly significant differences were detected between annual mean weights of TP/c/day and SP/c/day collected from high, middle, and low levels. These differences were manifested between high level and both middle and low levels, and between middle and low levels. It is clear that the highest mean weights of TP& SP were recorded for the high level[11.0g/c/d for TP and 7 g/c/d for SP]. On the other hand, the low level generated the least amount [2.4g/c/d for TP and 1.8 g/c/d for SP]. Very highly significant differences were detected between percentages of TP&SP collected from high, middle, and low standard levels. The differences were manifested between low level and both middle and high levels. The highest percentages of TP& SP were recorded for the middle level for TP[1.28% for TP and 0.9% for SP] while the low level generated the least [0.83% for TP and 0.61% for SP].

These weight generation rates of TP/c/day and SP/c/day in Alexandria in 1996 were extremely low compared with US generation rate in 1990 [181.6 g/c/day for TP].4 This can be attributed to that the demand for plastics has been influenced by level of per capita income and personal consumption expenditures. Furthermore, the American community is an extravagant one that encourages the through-away behavior that is inherent in highly developed countries.

It has ben found that the total quantities of plastics in the previous years of 1988 [20918 t/y] and 1995 [31390 t/y] in Alexandria are much more higher than that of the present study [6066 t/y]. Those quantities included rubber, leather, and plastics. For instance, in 1988 study, the percentage of plastics including rubber and leather was 5.3%[18], as compared with only 1.02% in the present study. In Alexandria, the plastic relatve ratio [V%/W%] is very high [6.9] if compared with those in Canada and

US[2.1-2.7]. The low ratio in foreign countries is due to shredding and compaction. It has been found that the annual percentage of TP in studies carried out in 1981 -82, of the Egyptian cities in 1986[1.5-3.1%] and 1994 [3.5-5.2%], and in 1986 data of Arab Cities [2-20%] were higher than that of present study [1.02%]. The same results have been obtained with other studies in 1985 [JICA study][6%], in 1988 [5.3%], and 1995 [5%] where their plastic results included definitely rubber, leather, and plastic. On the other hand, almost all Summer TP% surpassed those of Winter in Egyptian Cities.[11,12,13] This is in accordance with the present study.

It has been found that SP represents 72% of TP which includes PE and other resin types [Poly Propylene [PP], Poly Vinyl Chloride [PVC], and certain poly Ethylene [PE] containers] while RP represents 28% of TP which includes PS and others [PVC and PET] [Figure 2]. It has been found also that PE represents 59.3% of TP, while it consitutes 77% of SP.On the other hand, PS represents 14.9% of TP, while it represents 66.7% of RP. It is worth mentioning that the majority of TP is made of packaging of different types. This fact is in concordance with Das.[19] AUS study calculated the distribution of resin in plastic solid waste:PE [65.3%] and PS [17.1%], which is almost the same as in the present study.[19]

In tables [3 & 4], a significant difference was detected during summer season between percentages of PE and PS in RP collected from high, middle, and low standard levels. The difference was manifested between high level and both middle and low levels. It has been found that during Summer, the middle level generated PE% [84.1%] higher than the high level [48.9%] which can be explained by the fact that the high level recycled more plastic than that of other levels and thus its rejects are higher than SP. The highest percentage of PS in RP was recorded for the low level [70.7%] and the least was recorded for the high level[54.1%]. This can be explained by the fact that during Summer,children of low level eat take-away rice-lentil mixture in PS containers.

In Winter season, the highest percentage of PS in RP was recorded for the low level [75.6%] while the middle level generated the least [60.6%]. In Summer and Winter, the

highest % of PE was recorded for the middle level [82.7%] while the high level generated the least [63.1%]. Winter percantage of PE[78.4%] is higher than that of Summer [75.6%]. A highly significant difference was detected between percentage of PS in RP in the high level. Also, Winter percentage of PS in RP [69.2%] is higher than that of Summer [64.1%].

Processing of recycled plastics:

The junk merchants sell the baled plastic wastes segregated or unsegregated to local private recycling agent. The plastic wastes are transformed to clean pellets or flakes through some processing stages. These stages include: bale breaking , sorting, shredding, washing, drying , pelletizing, addition of colorants,and molding. Sorting is done according to the manufacturing method whether injection or blowing process, then according to the resin type in each process, followed by color classification of each resin type. The shredded and segregated plastic wastes are cleaned in two stages involving chemical washing with sodium hydroxide, then with water. The plastic is reshaped into pellets which form the raw material for the plastic manufacturers. Colorants are added to solve the problem of inconsistently colored pettets. Enough virgin resins having a high melting index are added to bring the average melt index of the material to a more favorable number. Finally, molding into products is performed pallets and toys to all possible plastic articles used at home. It has been found that the current methods of processing recycled plastics include many environmental problems especially air & wastewater pollution, and safety of workers.

Optimization of plastic recycling:

For optimization of plastic recycling, it has been recomended to implement successful minimization for plastic waste and/or recycling program. Minimization can be achieved through manufacturers, the consumer, and govern mental actions which include:

- Eliminating or reducing unnecessary layers of plastic packaging,
- Changing plastic products and packages design,
- Reducing plastic in packaging, change to

reusables/ refillables,
- Make commodities in bulk,
- Reduce toxic constituents,
- Bring reusable shopping bages to stores,
- Buy concentrated food items,
- Government guidelines for business [financial incentives/disncentives],
- Government education programs to public,
- Teaching the public how to reduce, reuse, and recycle plastics,
- Mobilize the consumers to participate in segregation to optimize recycling functions.

Finally,if plastic were to remain in use, and the current methods of disposal were to continue, then in future there would have increased problems with the disposal of plastic wastes. For Alexandria city, it is recommended to adopt reduction and recycling programmes for plastic wastes to achieve the optimum goals of solid waste management.

Conclusion and recommendations:

Almost all the mean weights of domestic solid waste [DSW] in Montazah district increase as the standard level increases. The generation rate of DSW in all levels in Winter was greater than that of Summer. The annual generation rate is 427 g/c/day. The generation rates of TP & SP in high and low levels in Summer were greater than that in Winter. n Summer and Winter, the middle level generated the highest percentage of TP& SP. The annual generation rates of TP & SP are 4.5 & 3.2 g/c/day. The highest prcentage of PS in RP during Summer and winter was recorded for the low level. Winter percentage of PE in SP and PS in RP are higher than that of Summer. In Summer and Winter, the highest percentage of PE was recorded for the middle level. The current methods of processing recycled plastics include many environmental problems.

Recycling is an important issue to reduce amount of waste delivered to open dumping, to conserve irreplaceable natural souurces, and to protect the environment. There is no lack of technology to prepare plastic wastes for recovery, the two problems are segregation and collection, and a market for the product. For optimization of plastic recycling, it has been recommended to implement successful minimization for plastic waste and/or recycling programs. The

minimization can be achieved through the participation of manufactures, consumers, & government.

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