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Analytical Evaluation of Polyethylene Terephthalate (PET) Bottle Waste Management Practices in Peshawar City and Recommendations for Improvement

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***Abstract*—** PET containers which are normally known as mineral water bottles are awesome material for use to both water and carbon dioxide and are reasonable for use in water and soda pops. They are utilized broadly in Pakistan and all around the World since they are practical, light in weight, simple to deal with, and break free. In contrast to its cost effective benefits if these PET bottles are not disposed properly then it has the potential to effect humans and environment in a severe manner. For the said reason a proper and comprehensive waste management practices has to be established. This research study focuses on the waste management techniques currently in use for generated PET waste in the city of Peshawar, and based on the information collected through field visits suggestion for its efficient disposal are incorporated. More emphasis is given to the choice for getting energy from utilized PET containers in an ecological amicable and practical way. The elemental analysis of PET bottles was performed in the laboratory using Laser Induced Breakdown Spectroscopy (LIBS), which is discussed in this study. In view of the examination results sort of cremation process with contamination control gadgets are proposed for their most extreme and productive control. At long last toward the end, the suggestions are proposed for viable PET waste administration.

Keywords—Polyethylene Terephthalate Bottles, waste management, waste to energy, incineration, recycling.

I. INTRODUCTION

The term “Plastic” is defined as a material system which can be made to flow or deform into a desired shape or form, usually under heat and/or pressure [1]. Plastics are divided into two categories based on how they react to heat and pressure: thermoplastics and thermosets.[2]. Plastic has a massive family tree with over 50 different family groups and hundreds of different varieties. This vast family of plastics has two main branches, one of which, thermoplastics, will be the focus of this research. [3]. Only five main branches are explained here, all of which are recyclable and well-known to the majority of people. PET stands for Polyethylene Terephthalate, HDPE stands for High Density Polyethylene, PVC stands for Polyvinyl Chloride, LDPE stands for Low Density Polyethylene, PP stands for Polypropylene, PS stands for Polystyrene, and Mixed Plastics stands for Polypropylene (Other) [4]In the year 2000, PET's manufacturing capacity was over 66 billion pounds per year, but the largest end use of PET is still fiber manufacturing, with bottle grade resin being the second largest market. PET bottle production surpassed 17.4 billion pounds per year in the year 2000. Bottle grade PET's consumption is increasing steadily to 7-8 percent, as its uses expand from water to carbonated water bottles, milk, wine, and beer [5]. The mineral water market represents an annual volume of 89 billion liters with a value of 22 billion US dollars. With a per capita consumption of 85 liters, Western Europe is the world's largest bottled water consumer. However, Asia and the Pacific are quickly catching up as potential bottled water markets, with annual growth of 15% from 1999 to 2001. [6]. The world's consumption is increasing at a rate of 7% per year on average. The application is so popular that, nowadays, a major component of world production of PET plastic is around 26 million tons in 2000 which is likely to rise to 55 million tons in 2011 [7]. In the beverage world, the country's bottled water industry is rapidly expanding. The country's market is very small on a global scale, with an estimated volume of 33 million liters per year at the end of 1999 [8]. According to a study conducted in 2001 by Zenith International, which also serves as consultants for the Asia Bottled Water Association (ABWA), Pakistan had the fastest growth of 140 percent in the year 2000, outpacing other Middle Eastern and Asian countries. [9]. At present two industrial estates has been established in the vicinity of Peshawar city. Hayatabad industrial estate which is situated on Jamrud road and spread over an area of 350 Hectors, it has more than 100 operational industrial units and six are related to plastic [10]. The rapid increase in population increased the demand of PET

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bottles for the usage of drinking water and beverages. This increased rate imposed serious environmental concerns which need proper waste management mechanism. Here in this study the data is collected and the mechanisms are discussed too. At the end of the study recommendations are provided for further improvement.

II. METHODOLOGY

A. Data Collection

1) PET bottle industry/production in Peshawar City

At present two industrial estates has been established in the vicinity of Peshawar city. Hayatabad industrial estate which is situated on Jamrud road and spread over an area of 350 Hectors, it has more than 100 operational industrial units and six are related to plastic.

Out of six units, five deals in PVC plastic pipe manufacturing and only one unit named Al-Hafiz Crestroplast (Pvt.) Ltd is working in manufacturing and supplying the PET plastic bottles to the local bottled water companies like H.H Enterprises with the brand name of "Zindigi", RG Enterprises with brand name of "National" and Aqwah" and Bikon Moya services with the brand name of "Khyber Aqua". PET plastic bottles for beverage brand like Amrat Cola is supplied from its manufacturing plant located in Gadoon Amazai, three units named Hamdard laboratories, Tops beverages, Spring (Pvt.) Ltd and Pepsi cola are not manufacturing the PET plastic bottles in Peshawar but import them from Fine Crestoplast (Pvt.) Ltd, Emgi Plastic (Pvt.) Ltd both situated in Lahore.

The other industrial estate is the Kohat road industrial estate, that has 65 units and is located on Kohat road. a total of 10 plastic units installed there which mainly deal in PVC plastic pipe and other types of plastic manufacturing businesses, only one industrial unit deals in PET plastic bottles named Wasay Laboratories (Pvt.) Ltd with a brand name of "Abaseen" is purchasing their requirement of PET plastic bottles from Al Hafiz Crestoplast (Pvt.) Ltd.

The names of the main industrial units situated in the vicinity of Peshawar and which use PET plastic bottles for filling of their products are; Hamdard Laboratories Waqaf Pakistan, Pepsi Cola (Pvt.) Ltd, Coca Cola (Pvt.) Ltd (Only storage unit), Amrat Cola (Pvt.) Ltd, Tops Beverages (Pvt.) Ltd, Spring (Pvt.) Ltd, Al Hafiz Crestoplast (Pvt.) Ltd (Manufacturing Unit), Wasay Laboratories (Pvt.) Ltd, H.H Enterprises, Biokon Moya Services (Pvt.) Ltd, R.G Enterprises.

TABLE I. GENERATION OF PET PLASTIC BOTTLES FROM THE CITY OF PESHAWAR

Sr.No	***Name of the Company***	***Total production***	
		Kg/day	***Metric Tonns/Yr***
01	Hamdard Laboratories	110.26	34.4
02	Al Hafiz Crestoplast	239.18	86.1
03	Pepsi Cola	2,112	760.32
04	Coca Cola	2,372	854
05	Amrat Cola	351.4	126.5
06	Tops Beverages	107	38.52
07	Other* brands	1,984	666.62
Total		7,276	2,566

*Other Brands includes Nestle, Boomer Cola, Refresher fruit drinks, Products of Murree Brewery etc.

Table I has been incorporated by conducting the visits for data collection of all of the above mentioned industries situated within the vicinity of Peshawar in order to attain the estimate of PET plastic bottle production.

2) PET bottles collection in city of Peshawar

The fate of these used PET bottles is determined by visiting the various waste dumping sites located around the city. During these visits it was revealed that the Rag pickers are efficiently collecting the PET waste and selling it to the scrap dealers or "Kabaries" so that to get paid from them, therefore PET bottle waste was hardly found at the dump sites of Peshawar.

In the table II there are 23 scrap dealers in the Peshawar out of which Saleem Kabari located at Murshadabad Kohati area, Momand Kabari located at Pando road and Shahjee kabari located at charsadda road are running their business on the large scale. These scrap dealers purchase the PET waste from other scrap dealers working on small scale and rag pickers on daily basis and supply it to the processors in Peshawar or mostly to Hattar and Gadoon industrial estates located at 155 Kms and 125 Kms respectively.

TABLE II. COLLECTION OF PET PLASTIC BOTTLES FROM THE CITY OF PESHAWAR

Sr. No	***Name of the Dealer***	***Total Collection***	
		Kg/day	***Metric Tonns/Yr***
01	Saleem Kabari	2,500	900
02	Momand Kabari	1,680	604.8
03	Shahjee Kabari	1,100	396
04	Warsak Kabari	650	234
05	Others	400	144
Total		6,330	2,279

*Others includes scrap dealers (Kabaries) working on small scale

3) PET bottle survey in Peshawar City

. Table III provides the results of the survey conducted in the city. A review of the waste dumpsites around the city revealed that hardly any used PET container can be found anywhere. This indicates that PET recycling (collection in particular) in Peshawar is approaching almost 95 %.

TABLE III. PET BOTTLE SURVEY RESULTS IN PESHAWAR

Sr. No	*Type of Businesses*	**Number**
1	Importers (Pre-forms only)	0
2	Bottle Manufacturers	1
3	Filling of Bottlers	6
4	Distributors	5
5	Rag Pickers	Numerous
6	Scrap Dealers	23
7	Processors	3-4
8	Re-users	1
9	Intermediate Businesses	2
10	Exporters	0

B. Practices in Use for PET Bottles Management at Peshawar

Peshawar's estimated population is over 2 million, with a 3.3 percent annual growth rate and a solid waste generation rate of 0.5 kg/capita/day, resulting in about 500 metric tons of solid waste produced daily. According to estimates, 12% of this waste is burned in the open, while a large portion of it remains along the roadsides, causing fugitive dust and bacterial pollution.[11]

The following agencies are in charge of solid waste management in Peshawar.

- Peshawar Development Authority (PDA)
- University Town Committee (UTC)
- Peshawar Municipal Corporation (PMC)
- Peshawar Contentment Board (PCB)

The fact that PET waste is non-biodegradable is a major environmental issue. This is why PET bottles are so long-lasting. However, it differs from paper and organic materials in this regard. Rather, plastic is photo degradable, which means that sunlight breaks down PET plastic into a small number of pieces rather than the basic elements that make it up. Although PET plastic waste generated in Peshawar is collected efficiently by the current waste management strategy, which is not implemented by any of the government organization but it is running itself by the small scale privately own businesses. But the main problem with the generated PET plastic waste from the city of Peshawar is that it is not utilized in a cost effective manner and only one approach is adopted and that is to supply the collected PET plastic waste to the PET bottles re-users and business which deals with export of PET flakes, above all these recycling businesses are not present in Peshawar but mostly in Godoon Amazia Industrial Estate, Hattar Industrial Estates and other cities like Lahore, Karachi. A handsome amount of revenue and energy is wasted on transporting this PET plastic waste to other industrial estates for recycling.

C. Potential PET Bottles Management Techniques

The techniques in use worldwide for waste management are discussed in Figure 1.

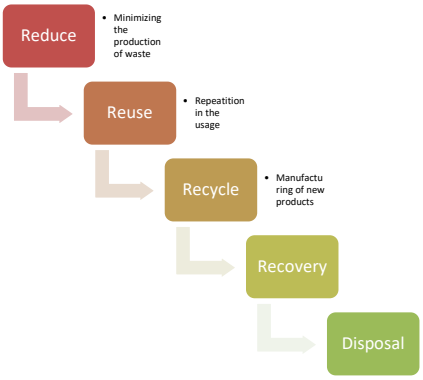

Figure 1. Hierarchy of Waste management

There are various terms such as waste avoidance or prevention, waste minimization, and they all refer to any action that reduces the amount of waste generated and thus contributes to the collective waste load.

- Waste generation should be avoided at all costs.
- The quantity of waste and its hazardous nature should be reduced at the waste source.
- Reduction in the quantity of products that are discarded before they become part of the general waste.

Reuse and recycling are not the only waste management options available to waste hierarchy reduction. Energy recovery is much more environmentally friendly and suitable than simply dumping waste in landfills. Although there are several methods for recovering energy, incineration is undoubtedly the most well-known. [12].

In Denmark, incinerators have a more than 100-year history, with the first plant opening in 1903. Two more plants were built before World War II, but incineration did not become widespread until the 1960s. The waste was considered a low-cost fuel for district heating production. Denmark's energy policy has favored heat and power generation since 1990. This holds true for waste incineration as well. [13].

In Pakistan, about half of the solid waste collected by government and private companies is recycled, whereas this percentage should be increased to at least 75% in order to keep our metropolitan environment practically clean. Obtaining this percentage comes at a high price.

The demand for waste treatment has increased as the population and waste generation rate per capita have increased. Currently, the disposal sites available for disposing of solid waste across the country are insufficient, and waste is mostly disposed of in open land, primarily in inundated areas, causing significant environmental damage.

In Pakistan, not a single city has an adequate municipal solid waste collection and disposal system. The majority of unattended solid waste clogs sewer lines and creates sluggish water ponds, posing a health risk to people nearby because these clogged sewer lines and ponds serve as breeding grounds for flies and mosquitoes that can spread diseases such as cholera and malaria.

A plant using HiRAD Technology has been established in the Landhi cattle colony in Karachi to effectively use cow dung and produce 25 kilowatts of electricity per day while also generating 2.25 tones of manure per day. Cow dung that was earlier thrown into the sea will be used to produce biogas, electricity, and manure.

According to sources, Karachi has a livestock population of one million. Landhi Cattle Colony houses over 400,000 cattle heads, or 40% of the total. [14].

It is the world's only colony with the highest concentration of animals in one location. This colony produces an estimated 8,000 tones of animal manure per day, which is dumped into the sea via a locally constructed drainage system.

III. RESULTS AND DISCUSSIONS

To verify and assess the components present in the synthesis of PET container a research center test known as Laser Induced Breakdown Spectroscopy (LIBS) was performed. The test was led in Environmental science research facility of Institute of Environmental Science and Engineering (IESE) NUST Islamabad. The arrangement is displayed in Figure-2

Figure 2. LIBS apparatus setup with PET plastic bottle sample

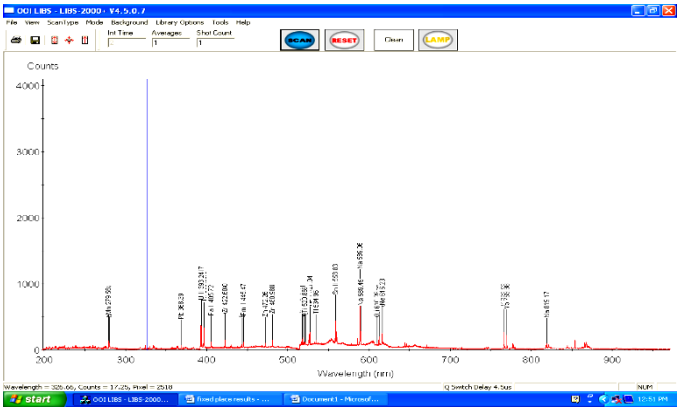

Figure 3. Graphical representation of LIBS-2000 V-4.5.0.7 distinguishing various components present in PET plastic sample

PET water bottle was sliced to made little size test samples and test was performed multiple times to figure out the average and exact outcomes. As per the analysis result, 38 components were identified which are recorded in a table IV.

TABLE IV. ELEMENTS DETERMINED IN LIBS TEST

Elements	Symbols	Elements	Symbols
Berkelium	Bk	Niobium	Nb
Beryllium	Be	Neon	Ne
Bismuth	Bi	Potassium	K
Chromium	Cr	Praseodymium	Pr
Calcium	Ca	Promethium	Pm
Chlorine	Cl	Protactinium	Pa
Copper	Cu	Samanium	Sm
Dysprosium	Dy	Scandium	Sc
Europium	Eu	Sodium	Na
Francium	Fr	Silver	Ag
Gold	Au	Strontium	Sr
Gadolinium	Gd	Thallium	Tl
Hafnium	Hf	Thorium	Th
Holmium	Ho	Titanium	Ti
Krypton	Kr	Tin	Sn
Lead	Pb	Zinc	Zn
Lithium	Li	Ytterbium	Yb
Magnesium	Mg	Zirconium	Zr
Manganese	Mn	Nitrogen	N

As many experiments and studies have demonstrated, the presence of chlorine in the incineration process can produce Dioxins and Furans, the results provided by LIBS are very accurate and supportive in selecting the type and design of the incineration plant, particularly the pollution control equipments. For example, the existence of chlorine (Cl) can form halogen acids and chlorinated compounds, since many experimental studies and studies have demonstrated that the presence of chlorine in the incineration process can produce Dioxins and Furans.

After reviewing the results of the LIBS tests, it was discovered that elemental analysis of PET plastic waste is indeed very effective in the decision-making process for the installation of an incineration plant that treats special segregated waste that can generate hazardous chemicals even after a complete control and effective incineration process, and the selection of pollution control equipment and processes.

IV. RECOMMENDATIONS FOR IMPROVEMENTS

The study is concluded with the following recommendations

- Peshawar is a trade city as in terms of Afghan transit trade a huge amount of PET plastic items are coming in market from other parts of the world which increases the amount of PET waste generation of the city and helps to maintain the continuous supply even in the winter season.
- Revenue can be saved by saving the haulage cost of exporting the PET waste to the other industrial estates and finally to China.
- PET waste generated within the city of Peshawar can be treated locally which will prove a cost effective approach.

- Regulations for the solid waste recycling in general, and PET plastic waste in particular, should be developed.
- PET plastic has a calorific value of 22.7 MJ/Kg, which is sufficient to power the turbine and generate electricity.
- Inspiration and understanding should be raised in the same way they are in other places of the globe to make sure that PET Plastic containers are properly disposed of and not burned or thrown away.
- Government officials, non-governmental organizations, educational institutions, and/or municipal employees should motivate and enforce training programs for the local community in collaboration with PET manufacturers to raise awareness about the end use of PET as an energy source.
- To make collection easier and more efficient, collection centers functioned and controlled by government in collaboration with producers for such materials must be placed or established in various locations throughout cities and villages.
- Rag pickers and waste collectors, also known as "Reddi Walas," should be given training.
- NGO's and the government should collaborate to end commercial reusability of PET bottles of water or other beverages.
- In order to implement and begin waste to energy technology in Pakistan, feasibility studies on the innovation must be initiated to gather data on the produced solid and plastic waste from cities around the country.
- Scrap collectors' social, health, and safety issues should all be investigated thoroughly.
- LIBS is a very effective technique for elemental analysis that is used efficiently and effectively in many developed parts of the world. It should be developed and implemented in instructional institutions and research organizations.

CONCLUSION

This study was conducted by gathering the information of PET waste production, consumption and collection within the city of Peshawar but due to the absence of any mechanism and waste to energy facility in Pakistan no real information can be collected on this. Pakistan does not have such a system; even the incinerators that are operational in the country are only for the intent of incinerating hospital waste and do not have pollution control equipment hence getting rid of hospital waste but generating air pollution with obnoxious chemicals.

The data collected from various companies producing PET bottles shown in Table-1 and collection entities incorporated in Table-2 reflects the trend of PET plastic production and collection comparison in the city.

Every year, and over one million tons of multiple plastic types are consumed in Pakistan, as per a conservative estimate. In Pakistan, the current production capacity of multiple raw material producers is around 300,000 tons. With a 700,000-ton deficit, this is hardly 30% of the estimated requirement. Imports make up for the shortfall, putting a strain on the country's economy [15]. This research is implicitly raising awareness of environmental issues of its subjects, in addition to examining the methodology of selecting pollution control equipment and methods. The main conclusion contain; the average production of the PET bottles throughout the city of Peshawar is approximately around 7 Metric tons per day takes a firm stance in favor of converting waste to energy by incinerating PET waste with such a high figure of PET waste production merely less than 1 ton/day is processed into PET flakes rest remaining waste is sent to the other industrial estates of the Province and to Lahore, Pakistan produces between 60,000 and 80,000 metric tons of PET flakes annually. Only a small portion is used by the reuse industry, with the remainder being shipped to China. There are significant investment opportunities in this area, and reuse businesses should be encouraged to promote increased PET waste incorporation. This would help to reduce the procurement of PET flakes-based products and relieve the fiscal burden on the country.PET recycling activities have low environmental impacts when particularly in comparison to other industrial processes where workers are exposed to harsh conditions. However, the country's current energy crisis has worsened to the point where the government has begun power cuts of compressed natural gas CNG once a week in order to use the gas to generate electricity. The rising tariff of electricity, roughly 16 to 18 hours of power cuts in 24 hours in most cities and villages; non-scheduled load shedding of electricity; power cuts due to the operational problems in power plants has forced the people to protest against the government's planning to handle this crisis, Although the Alternative Energy Development Board (AEDB) is active in this field, no project related to generating energy from municipal solid waste (MSW) generated in various parts of the country has been launched. Large-scale investment, research, and training are required to improve the technology of electricity production from solid waste in Pakistan, as this technology has been successfully adopted and used in many countries around the world for the past 60 years. LIBS analysis was conducted at the end, to gather data for elemental analysis and to determine the presence of various elemental ingredients of PET bottle which can help in devising air pollution control techniques.

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