Characteristics of Plastic Solid Wastes in Mosul City and Their Reuse

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Abstract. Moderately, plastic solid wastes become a main part of municipal solid waste production. Their importance lies due to non-degradable matter, not soluble, in addition to a light weight and large quantities. These characteristics make accumulate in increasing quantities on the surface of the globe and reach water bodies causing pollution in all its forms to wildlife and aquatic life. Six sectors including municipal and commercial areas were selected in Mosul city to study types of plastic waste and its compositions and characteristics. 432 samples of solid waste were collected and sorted to its components included plastic waste, weighted and measured their volumes. This study was accomplished from March 2018 up to August 2018. The study results showed that the plastic waste conforms 5% of dry weight and 12% of the volume of municipal solid waste. Fourteen types of plastic waste components were sorted from municipal solid waste. These include water bottles, soft drink bottles, oil containers, chairs, tables, water pipes, interior parts of vehicles, plastic bags, juice containers, plastic cups, CDs, Nylon, Acrylic and Silicone. Because of plastic waste is non-degradable matter, it will be accumulated on the surface of the earth and reach water resources causing pollution. Applying the sustainable development managements including, reducing the employment of plastic materials, reusing and recycling the components of plastic waste that must be done to increase their recycled products uses.

Keywords: Plastic waste, Solid waste, Mosul environment

1. Introduction

Solid waste in all components, especially plastic waste is causing problems to the civilians and the cities. The problem is accelerated due to the (negligence) of solid waste management systems and poor knowledge about the importance of solid waste as a continuous natural resource that accessible to everyone. The lack of awareness among officials about solid waste as economic resource and financial incentives in addition to lack of interest in environmental protection from waste pollutants make solid waste spread in the place of its production instead of using it. This behavior turns solid waste nuisance for citizens.

Solid wastes in all components are purely means [unuseful material in incorrect place] which can be separated, transformed, recycled and reused with large financial and environmental interest [1]. Solid wastes include all solid materials that the processor no longer deems of any adequate value to keep [2].

As lifestyle develops, the components and generation rate of solid waste differed. Plastic waste is one of the solid waste components that differ greatly. Plastic waste generation is considered a large environmental and public health problem everywhere in the world. This is due to increasing of population growth rapidly which generates a huge number of solid wastes and plastic waste is one of them. These vast amounts are non-degradable matter, not soluble, in addition to light weight and large quantities. These characteristics on the surface of the globe and then reach water bodies causing pollution in all the forms of wildlife and aquatic life. As a result, plastic waste polluted the environment and destroys resources. The amounts of disposed plastic are increasing day by day and it needs many years to degrade.

Plastic materials spread all over the world quickly. The advantage of plastic is that it's light in weight and possesses very good strength, toughness, durability and excellent shock absorption capacity. Plastic is corrosion resistant and chemically inert, low coefficients of thermal expansion good thermal and electrical insulation property. Plastic is waterproof and possess good binding property.
On the other side, the disadvantages of plastic are deformation under pressure, produces toxic fumes when it is burnt. Plastic wastes are often dumped in open areas instead of useful post usage. [3].

There are more uses for plastic materials in making disposable plastic products, for example, wrapping and covering materials, making plastic pipes for structure applications, electronic products, plastic furniture, and plastic parts for automotive applications. At the end, most of these plastic parts become junk, then disposed and creating street trash.

The aim of this study is to find the range of the problem, investigation the types, composition and generation of plastic trash as a main part of solid waste components, as well as their sources. This study will focus on the domestic and commercial regions producing plastic wastes as it represents the most daily common problem for people, as it closely related to human health and protection of environmental components and natural resources. This is a new strategy of sustainable development.

2. Literature review

Plastic is classified into two categories: Thermoplastic and thermosetting plastic. Thermoplastic examples are polyethylene, polypropylene, polystyrene and polyvinyl chloride. Themosetting plastic examples are Epoxy, phenol formaldehyde and urea formaldehyde. Plastic utilization has been increasing day by day. Plastic waste burning is a problem due to increasing in consumption and rapid urbanization. Plastic is a synthetic material that has a high molecular mass and can be molded into different shapes [3].

In Iraq, developing industries were rarely found, the domestic solid waste forms 50% or more of the total produced waste [4]. Therefore, these amounts represent 50% of the production rate in Mosul city. Several studies have been conducted on Mosul city to study the generation rate of total solid waste, the production rate has increased through the last years as evolving lifestyle and increasing the individual and family income. Table 1 explain briefly the variation of solid waste generation through decades by various agencies and authors.

| Domestic Solid waste (according to) | Total solid waste generation (kg/person. day) | Domestic solid waste generation (kg/person. day) |
|------------------------------------|---------------------------------------------|---------------------------------------------|
| Yousif (1988) [5]                  | 0.96                                        | 0.48                                        |
| UNEP (2003) [6]                    | 0.78                                        | 0.39                                        |
| Al-Wattar (2006) [7]               | 0.60                                        | 0.30                                        |
| UNOPS (2007) [8]                   | 0.70                                        | 0.35                                        |
| Al-Rawi (2007) [9]                 | 0.60                                        | 0.32                                        |

Nineveh governrate has an increased population of about 3 million people with 3.0 % yearly growth rate. Mosul city, the capital of Nineveh has more than 1.75 million people. The expected substantial amounts of solid waste are likely to be generated (1620 tons/day in year 2020) [10].

Mosul is a large city and contains many civilized landmarks as universities, factories, commercial areas in addition to large amounts of residential complexes which made it a rich, modern, and literate. Food preparation waste becomes less, while, the paper, packaging fraction and plastic waste increases [11]. On the other hand, during this period, most industrial factories and firms were not operating. Therefore, generated solid waste of these factories will not give reliable data.

3. Methods and Materials

In Mosul city, six areas (sectors) in the two sides (left and right sides of Tigris river) were selected for this study, that represent the main aspects and features of the whole city. People with different social, cultural levels and religions could be found in the selected areas. Random selection of houses and some commercial areas were made. These houses were single, multifamily, with and without children and infants, old, young. So on. Figure 1 shows an aerial photo of Mosul explain the selected areas of our study. People were asked to keep all solid waste components and garbage in bags at homes. Solid waste
samples were collected after (48 hours), that period was enough to consider the real waste samples. The contents of the collected bags were transferred and sorted in the laboratory. Each component was weighed, measured its volume and recorded, the total weight and volume of all the components checked against the original weight and volume of the samples, [12].

Figure 1: Aerial photo of Mosul city illustrate selected sectors for study

Solid waste samples were distributed through six months (12 every two weeks) (12 W) in six sectors of the city (6 S) with six locations in each sector (6 L) (residential and commercial locations). This study was accomplished from March up to August 2018. This period of time represents seasons of the year. A total of (432) solid waste samples were collected to cover greater areas of Mosul city.

Total collected samples = 12 W × 6 S × 6 L = 432 samples

4. Results and Discussions

The results show that the quantity and components of formed solid wastes differ greatly for all places during all times of the year. Many factors affect the characteristics of solid wastes, Cultural, factors economical levels, education levels. Some of these factors are level of culture and industrialization, social habits, and other environment factors like geology, geography, climate etc.

Generally, the production rate of solid waste varies according economic status and the higher percentage of the population that has produced a great amount of solid waste. Table 2 illustrate waste generation, initially decreases at the lowest income levels and then increases at a faster rate for incremental income changes at higher income levels, with 1.08 Kg/capita each day in Al-Magmoia Sector as a high value and decrease to 0.32 Kg/ capita each day in New Mosul as a low value. Also, the mean value for each sector varied from 0.80 Kg/capita.day in Al- Magmoia sector and decrease to 0.48 Kg/capita.day in Al Karama sector.
Table (2): Samples of production rate of solid waste in Mosul city (Kg/capita/day) (random selected samples of the studied areas)

| Sample No. | Sector 1 Magmoia | Sector 2 Hadbai | Sector 3 Al-Wahda | Sector 4 Al-Karama | Sector 5 Al-Nagar | Sector 6 New Mosul |
|------------|------------------|----------------|------------------|-------------------|------------------|-------------------|
| 1          | 0.87             | 0.64           | 0.55             | 0.36              | 0.72             | 0.42              |
| 2          | 0.78             | 0.72           | 0.63             | 0.38              | 0.55             | 0.44              |
| 3          | 1.08             | 0.78           | 0.65             | 0.41              | 0.52             | 0.60              |
| 4          | 0.88             | 0.82           | 0.58             | 0.47              | 0.66             | 0.55              |
| 5          | 0.60             | 0.64           | 0.55             | 0.53              | 0.63             | 0.62              |
| 6          | 0.95             | 0.66           | 0.62             | 0.60              | 0.52             | 0.43              |
| 7          | 0.76             | 0.62           | 0.48             | 0.56              | 0.62             | 0.40              |
| 8          | 0.80             | 0.54           | 0.42             | 0.49              | 0.50             | 0.56              |
| 9          | 0.60             | 0.68           | 0.49             | 0.32              | 0.44             | 0.38              |
| 10         | 0.66             | 0.58           | 0.52             | 0.39              | 0.40             | 0.32              |
| 11         | 0.71             | 0.75           | 0.45             | 0.38              | 0.66             | 0.36              |
| 12         | 0.80             | 0.61           | 0.60             | 0.51              | 0.48             | 0.58              |
| Average    | 0.80             | 0.67           | 0.55             | 0.45              | 0.56             | 0.48              |
| Min.       | 0.60             | 0.54           | 0.42             | 0.32              | 0.40             | 0.32              |
| Max        | 1.08             | 0.82           | 0.65             | 0.60              | 0.72             | 0.62              |

Figures 2 demonstrate urban solid waste production rates in two sides of Mosul, as a weighted average of the waste data available from different studied sectors. Disposed solid waste consists of many components on one hand. On the other hand, composition of the waste in general, differs based on the financial position of people as well as other environmental factors such as geographical location, energy resources, climate, living standards and cultural habits.

![Figure 2: Urban solid waste generation rates in Mosul city sectors](image_url)

Twelve components with different proportions formed the generated municipal solid waste from Mosul city citizens. The components include food and vegetables waste, paper and carton, plastics materials, classes, minerals, aluminum cans, cloth and diapers, wood, rubber and trimmings. It can be seen that food and organic waste represented a large amount of the total solid waste produced in Mosul which exceed 54% of the total waste weight, compared with (68.17%) organic waste components before [13]. Table 3 illustrate the components of solid waste and their percentage weight (%) according to the total weight of sample.
Table (3): Typical Component Percentage weight (%) of Mosul City produced Solid Waste (random selected sample)

| Sample No. | Food waste | Paper | Glass | Plastics | Metals | Al. cans | Textiles | Diapers | Wood | Rubber | Trimings | Misc. |
|------------|------------|-------|-------|----------|--------|----------|----------|---------|------|--------|----------|-------|
| 1          | 41         | 8.3   | 1.5   | 5.8      | 1.3    | 3.8      | 1.8      | 26.6    | 2.2  | 3.2    | 2.0      | 1.1   |
| 2          | 62         | 7.2   | 3.2   | 9.8      | 2.2    | 7.8      | 2.8      | 0       | 0    | 2.1    | 1.4      | 1.5   |
| 3          | 60         | 6.3   | 4.2   | 11.6     | 1.8    | 7.3      | 2.6      | 0       | 1    | 1.8    | 1.3      | 2.1   |
| 4          | 54         | 6.2   | 4.6   | 4.4      | 2.8    | 4.1      | 6.1      | 12.3    | 0.8  | 2.2    | 1.6      | 0.9   |
| 5          | 56         | 8.7   | 0.5   | 7.5      | 1.5    | 2.5      | 5.2      | 7.4     | 3.1  | 3.0    | 2.4      | 2.2   |
| 6          | 63         | 6.1   | 1.3   | 6.4      | 0      | 4.1      | 6.3      | 0       | 4.1  | 1.9    | 3.0      | 1.8   |
| 7          | 48         | 6.9   | 6.25  | 3.6      | 3.75   | 6.2      | 2.7      | 8.6     | 4.8  | 2.5    | 3.6      | 3.1   |
| 8          | 52         | 12.8  | 9.8   | 1.5      | 2.7    | 3.8      | 7.9      | 0       | 2.85 | 3.3    | 2.6      | 2.75  |
| 9          | 50         | 10.95 | 2.65  | 2.5      | 1.88   | 2.74     | 1.6      | 15.6    | 2.5  | 4.33   | 2.15     | 3     |
| 10         | 60         | 16.4  | 1.7   | 2.2      | 2.6    | 4.3      | 3.34     | 0       | 2.65 | 2.77   | 1.84     | 2.2   |
| 11         | 46         | 6.65  | 3.45  | 1.3      | 7.7    | 5.75     | 8.5      | 10.8    | 0    | 3.8    | 2.95     | 3.1   |
| 12         | 56         | 4.4   | 3.15  | 4.5      | 0      | 3.1      | 4.6      | 19.5    | 2.15 | 0      | 1.25     | 2.35  |
| Average value | 54   | 8.31  | 3.46  | 5.1      | 2.35   | 4.45     | 4.47     | 8.81    | 2.21 | 2.56   | 2.16     | 2.16  |
| Min. value | 41         | 4.4   | 0.5   | 1.3      | 0.0    | 2.5      | 1.6      | 0       | 0    | 0      | 1.25     | 0.9   |
| Max. value | 63         | 16.4  | 9.8   | 11.6     | 7.7    | 7.8      | 8.5      | 26.6    | 4.8  | 4.33   | 3.0      | 3.1   |

Because solid waste comes from many sources, it naturally contains an almost unlimited variety of materials with different percentages. These vary in size and constituents of domestic and commercial wastes are fermentable organic matters; glass, wood, metals and plastic with relative proportion depending upon many factors. Quantities and composition of solid waste also vary over the year with changes in diet, packaging, etc.

Each component is applicable one or more of the principals of solid waste management, that are reduce, reuse recycled & recovered to investigate the goals of sustainable development. The level of applying those principles depends on the citizen's culture and awareness of the importance of dealing with waste as a permanent economic resource. These reflect the extent of the sense of responsibility in the middle east countries. Figure 3 shows the range of solid waste components (min. and max percentage) in addition to the average.

The density of waste changes at different stages, it varies significantly between generation, transfer vehicles and final disposal. This difference due to handling, moisture content changing, densification and increasing density due to vibration of movement. Also, density of solid waste in (gram/cm³) depends on the percentage rate of components, in addition to the case of solid waste if it had significant effect or not and the degree of compaction. Generally, the density ranged between (0.50gram/cm³ up to 1.1 gram/cm³), as an average of (0.72 gram/cm³).

Fourteen types of plastic waste components were sorted or classified from municipal solid waste. These include water bottles, soft drink bottles, oil containers, chairs, tables, water pipes, interior parts of vehicles, plastic bags, juice containers, plastic cups, knives and spoons, CDs, Nylon, Acrylic, Silicone. Table 4 clarify plastic elements of the plastic waste component, chemical name of plastic, symbols of plastic materials, their percentage weight and the density.
Figure 3: Range and average weight percentage (%) of solid waste components (min. and max percentage weight)

Table 4: Plastic waste component after sorting to many categories

| Plastic waste          | Plastic Type                        | symbol | % weight from plastic component | Density gm/cm³ |
|------------------------|-------------------------------------|--------|---------------------------------|----------------|
| 1 Water Bottles        | (Polyethylene terephthalate)        | PET    | 14.5                            | 0.93           |
| 2 Soft Drink Bottles   | (Polyethylene terephthalate)        | PET    | 20.6                            | 0.97           |
| 3 Oil, detergent       | Container (Polyethylene terephthalate) | HDPE   | 7.9                             | 0.98           |
| 4 Chairs, Tables       | High-Density Polyethylene           | HDPE   | 6.6                             | 1.02           |
| 5 Water Pipes          | Polyvinyl chloride                  | PVC    | 3.1                             | 1.05           |
| 6 Parts of Vehicles, Appliances | Polyvinyl chloride | PVC | 8.3 | 1.03 |
| 7 Plastic marketing Bags | Low Density Polyethylene | LDPE | 9.8 | 0.4  |
| 8 Juice Cans           | High-Density Polyethylene           | HDPE   | 7.7                             | 0.52           |
| 9 Plastic Cups         | Polypropylene                       | PP     | 4.7                             | 0.65           |
| 10 Knives and Spoons disposable | Polypropylene | PP | 4.6 | 0.65 |
| 11 CDs, DVD            | Polystyrene                         | PS     | 2.1                             | 0.95           |
| 12 Nylon               | Other plastic                       | Other  | 4.2                             | 0.80           |
| 13 Acrylic             | Other plastic                       | Other  | 3.7                             | 0.96           |
| 14 Silicone            | Other plastic                       | Other  | 2.2                             |                |
Water bottles and soft drink bottles are PET type of plastic for one time use only. Because it contains toxic chemical, therefore exposure to solar heat and washing may leach the chemical out affecting on the liquid inside, [14]. Micro plastics will be released from water bottles and reach individual drinking the water causing many health problems. PET is safe specially for one use. While oil, detergents containers, remain of chairs, tables and juice cans are made from HDPE which is durable strong plastic, and it is thermo plastic [15]. HDPE plastic must be maintaining in safe healthy conditions away from high temperature and sunshine.

Pipes and interior parts of vehicles are made from PVC which is a thermoplastic polymer and its fire resistant. PVC plastic releases chlorides which contain dioxins or toxic hydrogen chloride gas when heated during its production, causing environmentally harmful [16]. Plastic bags are the most common material for commercial use which are made from LDPE, its very low-density forms used in flexible matters. It is recycled material. Polypropylene is a thermoplastic polymer; it is also copolymerized with ethylene. Disposable cups knives, and Spoons are made from it, due to its high resistance to heat, [15]. Polystyrene is a petroleum-based plastic used in the hard form or in the form of Styrofoam, a transparent plastic. CD and DVD are plastic materials made from PS, in which is dangerous for health and reactive to heat (inflammable). Other types of plastic like Nylon which is called polyamides and it is a thermoplastic. Acrylic is another type of plastic found as a plastic waste. It is used instead of class. It is a polymer called polymethylacrylate (PMMA). Acrylic is a hard substance for glasses of aquariums, aircraft windows, blinker lights of automobiles. Silicone is the last type of plastic waste component sorted from solid waste. Silicones are synthetic compounds bound to carbon, hydrogen and oxygen. It is heat resistant and flexible like rubber. Often used as an adhesives and lubricant matter.

The density of each element of collected plastic waste is recorded in table (4). The average value of density is about (0.62 gram/cm³), it ranges between (0.4 gram/cm³ up to 1.05 gram/cm³) as a component difference. Plastic waste takes up space 12% of the total volume of all waste components.

**Figure 4:** Plastic components as percentage weight

### 4.1. The strategy to reduce plastic waste

Applying the strategy of solid waste management is important to reduce the disposition of solid waste to the environment, plastic waste is one of them. The strategy is useful in sustainable solid waste to help save natural resources that are not renewed, it is also important in decreasing the environment pollution and helping to save and recycle energy production processes.
4.1.1. Reducing plastic materials is the first principle of solid waste management. Some plastic items can be replaced with other materials, such as water bottles and soft drink bottles which can be replaced with glass bottles. Glass bottles can be reused many times. Shopping Bags can be replaced with paper bags which can be degraded quickly, especially the percentage weight of these three items represent only 43.9% of the total weight of plastic waste.

4.1.2. Reusing plastic. is the second principle of sustainable management because plastic materials have more advantages making it reusable many times without changing its characteristics. Generally, the majority of plastic can be reused for the same or other purposes. Water bottles, Soft drink bottles, containers of oil and other shopping bags, cups, nylon and acrylic are frequently can be reused many times after washing and cleaning. But it must be made efficiently to be reused many times. Also, the plastic materials must be sold and not give free to encourage people to reuse it.

4.1.3. Recycling. is the effective method for managing non-reusable plastic waste materials. These components founded after collecting then sorting. Most of the plastics are recyclable, but recycled plastic is more dangerous to the environment as these plastic products contain additives and colors. Recycling plastic material can be done 2-3 times and plastic material deteriorates because of thermal pressure and durability decrease, [3].

Recycling plastics saves; landfill space, energy, water, resources, and reduces pollution. Furthermore, plastic is derived from oil which is a depleting natural resource. There are some useful techniques available to manage the plastic waste such as recycling, incineration and landfilling. Recycling of waste plastic is an excellent technique. In this technique there is a need for selection of plastic wastes for recycling while landfilling is a less conventional technique to eliminate the plastic wastes and space for landfill.

4.1.4. Incineration technique. is helpful in the reduction of the need for landfills of plastic wastes but in this technique toxic substances are released into the atmosphere. Non-recyclable materials, toxic plastic containers, rubbers, plastic waste from medical uses must be incinerated. Incineration achieves many benefits such as, protection of surrounding environment from toxic materials, disposal of plastic waste in addition to generate heat energy.

There are some new technologies developed to utilize the plastic wastes and blend the plastic with other polymers such as reconstruction of the bitumen coated road by plastic wastes. Plastic waste can be used as fuels in some process applications, in which plastic waste can be heated at very high temperature and converted into a liquid and gas.

5. Conclusions
Plastic waste is a non-degradable matter, therefore its components which exceed fourteen items or more will be accumulated on the surface of the earth and will reach water resources causing pollution of the environment after reaching wildlife and aquatic life. Anyhow plastic wastes will be reduced and the amount reaching the land or water bodies will shrink. This strategy can be applied by reducing the amount of plastic used with others. Reuse plastic many times to reduce the amount of new plastic materials and decreasing plastic waste.

Plastic waste can be used in energy production or in co-processing. Also, recycling plastics to produce new materials from non-useful ones is essential for environmental recovery and important to ensure the safety of all living organisms. Plastic waste materials are used as a filler for pavements and Street cladding. Best possible solution is avoiding non-degradable plastics by finding proper biodegradable substitutes. It may take a long time to get rid of plastic wastes from the environment, it is essential for environmental organizations to keep monitoring and implementing proper waste management and recycling systems.

6. Recommendations
In order to reduce the environmental side effects of increasing plastics production, use and disposal, several proposals are available.
1- Better waste management systems.
   a- In the using place, by reducing the usage of plastic and or reuse plastic materials several times.
   b- by making easy higher waste aggregation and recycling rates, (Primary recycling, secondary recycling or mechanical recycling, Tertiary recycling or chemical recycling, [3]) would permit waste plastics to be restrict and decrease before collection to create problems of pollution in the environment.

2 – Modification in product design.
   a- such as, using other materials instead of plastics which could reduce the production usage and disposal of plastics in the first instance.
   b- Production durable plastic materials to reuse it many times instead of cheap single uses materials.
   c- Focusing towards bio-based or biodegradable plastics, this could reduce the environmental adverse impacts of plastics more directly by reducing their environmental bad effects.

3- Clean up and treatment activities.
   a- Clean-ups and developed technological apparatus to collect plastics before reaching lands, beach, river sides. This will permit plastics to be removed already in the initial subtraction areas and product natural environment.

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