A study on solid waste generation, composition and management in Sulaimania city, Kurdistan region, Iraq

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Abstract. Municipal solid waste management became a major challenge due to the population growth, change of lifestyle in Sulaimania city, especially since the urban expansion increased from 2003, and when many villages in the countryside had already become a part of the city. The major part of generating solid waste in Sulaimania disposed in the Tanjaro area (an open dumping area southeast of Sulaimania city) without any treatment or proper landfilling. In this research, the compositions of generating solid waste of Sulaimania city and its properties were determined. Also, in this research, it was found that household waste generation is threatening the environment of Sulaimania city due to the huge amount of the produced leachate of solid waste which flowing into the Tanjaro dumping area and ultimately contaminating groundwater, surface and subsurface soil there. This research covered 12 different subzone areas within 5 major zones across the city a covering nearly 300 house samples. Also collected solid waste samples were categorized into the kitchen, plastic, glass, electronic and some other types of solid wastes. The results showed that the number of houses generating more than 2 kg of solid waste per day is higher than those with less than 1 kg generated solid waste. It has also been inferred that the highest composition ratio of household solid waste was kitchen type and reached (63.1%) followed by plastic-type solid waste (10.2%), cardboard (5.4%), cans and other metals (2.8%), Glass waste (2.7%) and E-waste (0.1%), other wastes such as textile, nylon, wood and lethal around (15.7%). Besides that, the results showed that the amount of the waste is seasonally changing, for example, the amount of solid waste from April to October is higher than other months due to increasing human activities for producing solid waste. Furthermore, this study covered a survey of the main medical waste from 25 clinics across Sulaimania city and counted the main waste contributed elements of the medical waste that produced. The variation in the generation rate, varied and excuses for this variation clearly stated. Also, the clinic medical waste generation was also investigated for their constituents and quantity and also the possibility of its segregation and ways to dispose of it. All the clinics private and public ones were investigated and studied for having chimneys and the possibilities of air pollution due to the burning of the medical waste.

Keyword: Sulaimania city, Household solid waste composition, Tanjaro dumping area, medical waste generation and management, Clinical waste.

1. Introduction

Nowadays; one of the main raising problems is treating the generated solid waste that is produced daily. Few of the developed countries are treating the solid waste using an ideal solid waste management system including recycling or recovering energy and as the last step; the waste will be dumped into a sanitary landfill area. On the other hand, the majority of developing and under-developing countries have no plan for proper tackling of solid waste generation, instead, their generated solid waste is either dumped into deep oceans or into open areas without a proper scientific way of management and treatment. Municipal solid waste management (MSW) is a major challenge due to the increase in population, the change of lifestyle in Sulaimania city, and the urban expansion following the 2003 year in which many of the villages in the countryside had already became a part of the city are considered as major challenges for the environment of the city. The Problems were raised when the majority of the
generated solid waste was and still disposed in the Tanjaro area (an open dumping area southeast of Sulaimania city) without any pre-treatment or proper landfilling. It was found that in the collected samples of municipal solid waste of the city, the household waste generation is threatening the environment of Sulaimania city due to the high-level amount of solid waste generated leachate which is flowing in the Tanjaro dumping area and ultimately contaminating its groundwater, surface and subsurface soil.

Sulaimania city like the other Iraqi cities; faces the increasing of the solid waste quantity due to the population growth and urban expansion it’s about 730K capita [1]. This means waste generates also increasing in Sulaimania city without any segregation process which includes (industry, agricultural, household, E-waste) that is disposed to the Tanjaro landfill. The total waste generation per day in the city centre of Sulaimania is nearly around 1,200 tons/day and in the countryside, it is 2400 tons/day. The type of the wastes found in Tanjaro is household waste, medical waste, hazardous waste and industrial waste (Hoornweg and Bhada, 2012).

According to the primary data that had been taken from the stakeholders in the Sulaimania city study area, organic waste has the highest ratio of solid waste compared to other types of wastes. Also, the data which was collected from surveying the households and separating the waste manually in the Tanjaro dumping area showed that the highest ratio of waste in Sulaimani city is organic waste and the rest of the wastes are (plastic, cartoon, agricultural, E-waste, etc.). In this study, it was found that the highest ratio of solid waste generated was organic waste and mainly produced from the kitchens. Increasing the ratio of the generation of the household solid waste in Sulaimani city is a new challenge for the city due to the lack in having advanced methods to treat the solid waste from just being dumped and not being recycled at larger scales. The household solid waste from Sulaimani city is highly mixed together and contains organic and inorganic wastes and therefore; it is hard to separate them before going through any processes. This research was to identify the composition of generating waste in Sulaimani city and then suggest a better mechanism for tackling this issue compares to the current method, which is dumping it in the Tanjaro dumping area.

2. Literature reviews

Globally, about 70% of municipal solid waste disposed of in landfills and containing a high level of hazardous substances such as paints, vehicle maintenance items, mercury-containing waste, pharmaceuticals, batteries, and numerous different items (Dana Adamcová, 2015). In Japan, the regulations and guidelines that are forming a framework for the technology are reviewed and the historical background and the present state of Japanese municipal solid waste (MSW) were checked to pass through analysing the collected data from organization booklets, changing the method of the leachate treatment system survived at the end of the process, and the sustainable bioreactor landfills with low organics were proposed. (Nobutoshi Tanaka, 2005). In Iraq, with a population exceeding 40,508,473 million capita [1], with rapid economic growth in some of the cities and a high rate of population growth with a relative increase in the individual income and sectarian conflicts, all have led to worsening the problem of solid waste generation in the country. At 2016, Iraq estimated to produce 31,000 tons of solid waste every day and an average solid waste generation exceeding 1.4 kg/capita/day (AlNajjar, 2016). One of the barriers to establishing and improve solid waste management, planning, monitoring has always been the lack of sound, reliable, comparable and available data. The use of unreliable data will lead to poor policy-making decisions and the establishment of inappropriate waste management infrastructure (Christian Zurbrugg, 2002). The generation of solid waste its composition in Baghdad is typically affected by population growth, urban, improved economic conditions, improved collection service, changes in lifestyles, social and cultural habits, social development, income class composition, and diffusion of technical competence (EECCA, 2002). In Baghdad, the examination presumed that normal generation rates of organic waste were 0.396 kg/capita.day, cellulosic squander was 0.072 kg/capita.day, and the total solid waste generation was 0.673 kg/capita.day (Chyad, 2016). Mosul (the second largest city in Iraq) like the other different urban communities in Iraq, is facing difficulties in all issues at all the phases of the solid waste management system including the collecting, arranging,
transportation, and transferring of the solid waste. The population of Mosul city reached 1.52 million inhabitants and a 3.0% growth rate with a generation of more than 377264 tons of solid waste per year or 1033.6 tons every day. It was concluded that each individual of Mosul city generating an average of 0.68 kg/capita. day and that the higher composition rate was dominated by organic and food constituents. It showed that social and economic views as well as the present instability and unsafe conditions of the country had a considerable impact on both generation and composition of solid waste (Sati and Taha, 2017). The third-largest city in Iraq, which is Basrah, also suffering from insufficient solid waste management also, in such a manner that the waste-collecting is attempted in certain urban regions and then will be transferred to an uncontrolled dumping destination area. (Sherien Elagroudy, 2011). The quantity and the quality of the household solid waste composition in Erbil city were determined in Erbil city in spring 2009 where 184 samples from 50 different houses with different incomes were analysed. The solid waste generation in Erbil city reaches approximately 400 tons/day and 12,002 tons/month. Besides that, the solid waste generated rate is 0.420 kg/capita. day, in which %76 is foodwaste, %5 is plastic, %4 is glass and %3 metal, and the constituents of the recyclable material reached 85.87% potentially and 13.79% recycling (Shekha, 2010). Municipal solid waste (MSW) in Kirkuk city represents a difficult issue having adverse effects on the condition and wellbeing of the individuals. Both the amount and the volume of MSW have been proceeded due to the fast increase of the population. The population growth rate of inhabitants in Kirkuk city has reached 3% per year in the previous decades and the population of Kirkuk city was predicted and was increased from 1,050,000 in 2008 to 1,445,556 in 2020. The daily solid waste generation was projected to 1000 tone in 2011 and, the daily solid waste will add up to 1200 tons by 2021. (Sameera S Mustafa, 2013)

In Sulaimani city, the total solid waste generation per day in the city centre is 1200 tons/day and in the countryside, it is 2400 tons/day. The type of solid wastes found in Tanjaro is household waste, medical waste, hazardous waste and industrial waste (Hoornweg and Bhada, 2012). Besides that, probably lack of environmental awareness, lack of environmental law enforcement and punishment and bad-quality products help in increasing the amount of solid waste generated in Sulaimani city. In addition, an increase of population in the city along with the increase of Syrian and Iraqi refugees were 257000 Syrian refugees and 1,003,300 Iraqis migrated at the beginning of 2015 (Hoornweg and Bhada, 2012).

3. Practical work and Methodology

In this study, work was to accurately segregate household waste in order to determine the ingredients of the waste and the study covered around 12 different areas inside Sulaimani city, collect samples from 300 houses. So, this research was to determine the household waste composition in Sulaimani City to evaluate the current scenario of tackling generated waste in Tanjaro's dumping area and finally to suggest the best possible way to minimize the negative impact of dumping waste improperly on the environment of the city. In this research, the practical works were divided into two parts, each part include two sections from a different point of the source as in the following: Primary data is one of the crucial parts of research and it can be divided into three main parts documentaries, multiple sources, and surveys. The surveying was used to collect reliable data from being more accurate research. In this study, three hundred questionnaires sheets have been distributed over twelve different zones inside Sulaimani city. Each of the zones included 25 sheets and each sheet consists of 9 questions. The second part of the practical work was collecting samples from different trucks reaching the Tanjaro dumping area which came from different zones of Sulaimani city. Random methods were practiced for the purposes of having samples from the whole city and the solid waste samples were manually segregated. The purpose of the segregation process was to calculate the real ratio of each type of solid waste constituents to be compared with the data collected from different stakeholders. Furthermore, more solid waste samples were collected from 25 clinics which were mainly focusing on the amount of clinical waste generated with its components. The following questionnaires were distributed among the clinics as follows: For collecting the secondary data, different companies that are in charge of collecting waste in Sulaimani city, namely (Qubad, Khalid Shinky, Shkar and Harem companies) were visited in order to observe the
current applicable methods for collecting the waste inside the city. These companies are private companies that work based on an official contract between them and the municipality of Sulaimani city. Furthermore, data were collected from the municipality of Sulaimani in order to make a comparison between the data being collected from Tanjaro with their provided data. Also, the collaboration between the municipality and the current companies for collecting waste was observed.

4. Results and discussions

After the questionnaire was randomly distributed among the public from different zones inside the city. The feedback for each question was accurately analysed as in the followings:

Figure 1 shows that the majority of people from zones of Mamostaian, Aqary, Ali-Nagi, Ashty and Bakrajo generating around 2 kg of solid waste per day while the majority of residence from Chwarbax, Shex-Mhedin, Wllwba and Sharawani generating nearly 4kg each day. This is probably due to the difference between the lifestyle of people living in those areas and the difference between the incomes of the families in both zones.

Figure 2 shows that the majority of the generated solid waste from the houses in Sulaimani C. city is organic and this is due to the common culture of the society that the majority of people prefer to dine at home. On the other hand, some of the households believed to have both Organic and Inorganic wastes at home.

![Figure 1: Average daily solid waste generation rate in different areas inside Sulaimani City.](image1)

![Figure 2: Classification of household wastes to Organic and Inorganic solid waste.](image2)

Kitchen waste was the highest among all other types of waste as in Figure 3. This might be due to the culture of the majority of people in Sulaimani dining at home and ultimately generate more kitchen waste than others. The majority of the households not willing to practice the segregation process at home Figure 4. This is due to a lack of environmental awareness among individuals and also lack of encouragement by government and private sectors in practicing a recycling process on the other side. If there is a recycling facility or Material Recovery Facility (MRF) in the city, then the company could exempt households from the solid waste bills, or giving them credits for the segregation process, then households could easily do that figure 5.It’s clearly shown that the majority of people from different zones were not using separate bins for specific type of waste. The issue is strongly related to not practicing the segregation process at individual homes and lack of environmental awareness. Besides that, even if the households segregating their own waste and using the special bins for the specific type of waste at home still the separated waste cannot be collected by different and special trucks for such waste. This is due to not having recycling and MRF facilities in the city. The majority of people believe that seasons will have an impact on the waste generation ratio as in Figure 6. This might be due to the fact that in summer most of the households are off at home and spend their time at home. It will ultimately generate a huge amount of waste compared to winter and spring where many people spend their time at work and dine outside instead.
Figure 3: The highest ratio of the generated solid waste from households.

Figure 4: Waste segregation practice at home from different zones.

Figure 5: Using a special bin for segregating a specific type of waste.

Figure 6: The effect of seasons on the generation of solid waste.

Illustrates the majority of people in many different zones in Sulaimani city attempting to reduce their household waste Figure 7. In some of the areas like Ashthy, Ali Naji, Mamostaian and Aqary, people are willing to reduce their household waste while in some other areas like Wllwba, sar Shaqam and Sharawani, the ratio still is low. The difference might be referring back to the difference between lifestyle and level of education in both zones. Shows that majority of people mixing all types of waste, including electronic waste as well Figure 8. It is very obvious that mixing such hazardous waste with other types of non-hazardous waste is dangerous and ultimately damages the environment. This might be happening for the same reasons of unavailability of recycling and MRF facilities in the city. Few areas like aqary, ashthy, ali naji and mamostayian showed that they are not combining e-waste with other wastes and this is probably due to the level of education of individuals are higher than in other areas and this will lead them to practice such activities.
The majority of households in Sulaimani city have no idea about solid waste management and the way they tackle the waste in the Tanjaro dumping area Figure 9. This might be due to the fact that the level of environmental awareness is very low and in the country’s education system, environmental subjects and courses were ignored. Thus, people do not know how their waste is going to be treated and which scientific method is necessary to be practiced in order to minimize the negative impact of the current practice of solid waste disposing methods. The composition of the collected samples of solid wastes from the landfill area of Tanjaro is clearly shown in terms of weights and percentages in Figures 9. The plastic came as the second-highest ratio among all the types of waste this is due to the wide range of using plastics in every daily activity at home. Glass and paper wastes came as third and fourth types of waste respectively. Several data were collected, which mainly covers five different zones inside Sulaimani City as shown in the Figure 10 which shows that the highest ratio of the collected waste is Nylon, then cartoon and Plastic respectively.

![Figure 7: Practicing waste reduction at home.](image1)

![Figure 8: Combining E-Waste with other types of wastes.](image2)

![Figure 9: Percent household solidwaste in different areas.](image3)
Figure 11 shows that the amount of waste generated per month in Sarkarez and Ashaba Spi is higher than in the rest of the places. This could be referred back to the fact that both areas mentioned were located in the centre of the city and very crowded due to having many shopping malls, markets and small businesses, unlike other zones where the majority are residential areas with few shops and mini markets.

Figure 12 above showed that in Zone 1, the highest ratio was organic and this is due to having a more residential area comparable to the other zones. In the Zone 2, plastic was higher than in other zones. This is due to the fact that zone 2 is covering the bazaar and city centre where many shopping malls and small businesses are there and as a result, the huge amount of plastic bottle and other forms of plastic is generated.

Figure 13 shows that in spring, the amount of organic waste is still higher than other types of waste. This is due to having a lot of holidays during spring and many people will stay at home. As a result, kitchen waste is increasing compared to other periods of time. Furthermore, the organic waste generation in Zone 2 increased compared to the same zone. This is due to the fact that people visit city centre and bazaars during spring of time more than another season. Organic waste during the summer still is higher than other types of waste Figure 14. This might be due to having a school holiday and the majority of people prefer to stay at home due to hot weather. Hence, kitchen waste is increasing dramatically.

Organic waste is declining in zone 1 and increasing in zone 2 compared to the third spring Figure 15. This is due to the fact that the majority of people are working during fall and school is opened and ,
the city centre is receiving fewer visitors compared to other zones. This cycle of waste generation will continue seasonally with a probability of minor changes in different zones. In this study the amount of waste generated per day for each zone was determined as shown in Figure 14 in which the amount of organic waste including kitchen waste was higher than other types of waste in Zone 1. Because, in Zone 1, the large area in the city contained a large amount of organic waste which is around 1170 Kg per day. Plastic waste was coming as the second-highest ratio of generating waste in zone 1.

Figure 13: Amount of waste generated in four different zones Kg/ day, in spring

Figure 14: Amount of waste generated in four different zones Kg per day, in summer

Figure 15: Amount of generating solid waste in four different zones Kg per day in winter
The amount of waste generated in winter in all zones one to four and the constituents in Kg per day are shown in zones one, two, three and four Figure 16.

Figure 16: Amount of generating solid waste in four different zones Kg per day in winter
The study was also conducted in different clinics to estimate the current clinical waste scenario inside the city. In most of the clinics, the amount of generating waste was less than one ton per day except a few of them were generating greater than One Ton as shown in the table below (Table 1). Classification of the main types of waste generated in this hospital was as in Table 1. Placing any filter for preventing the emission of the dangerous gasses that resulted from burning results were as in the below:

| I | Name of the Clinic        | chimney burners | waste segregation | preventing the emission | R, tone/day | Main types                                      |
|---|---------------------------|-----------------|-------------------|-------------------------|-------------|-----------------------------------------------|
| 1 | Saholaka clinic           | Yes             | Yes               | Yes                     | ≤1          | Needle + Gauze                                |
| 2 | Tuimalik hospital         | Yes             | Yes               | Yes                     | ≤1          | Tube + Tube gel + Antop + Gauze               |
| 3 | Soma hospital             | Yes             | Yes               | Yes                     | ≤1          | Pathogenical Waste + General Waste           |
| 4 | Faruq hospital            | Yes             | Yes               | Yes                     | ≤1          | General Waste + Infectious Waste + Sharp Waste |
| 5 | Shaxawan Clinic           | Yes             | Yes               | Yes                     | ≤1          | Tissue + Gauze                                |
| 6 | Heart Clinic              | Yes             | Yes               | Yes                     | ≤1          | Tube + Tube gel + Gloves + Gauze             |
| 7 | Aram Jamal Clinic         | Yes             | Yes               | Yes                     | ≤1          | Gauze + Cotton + Pathogenic Waste            |
| 8 | Dentist star hospital     | Yes             | Yes               | Yes                     | ≤1          | Gloves + Infectious Waste + Sharp Waste      |
| 9 | Meer Clinic               | Yes             | Yes               | Yes                     | ≤1          | Tube + Needle + Tube gel                     |
| 10 | Victory Clinic            | Yes             | Yes               | Yes                     | ≤1          | Gloves + Plaster + Syringe + PRP             |
| 11 | Dr. Nawzad Clinic         | Yes             | Yes               | Yes                     | ≤1          | Syringe + Paper + Plastic and Mask           |
| 12 | Runaki Hospital           | Yes             | Yes               | Yes                     | ≤1          | Bloody Cotton + Human Skin + Operational Knife |
| 13 | Victory for Skin          | Yes             | Yes               | Yes                     | ≤1          | Surgical waste + Tube + Syringe + Gloves + Cotton |
| 14 | Ara Beauty Clinic         | Yes             | Yes               | Yes                     | ≤1          | Needles + Wax strips + Cotton wool buds      |
| 15 | Royal Hospital            | Yes             | Yes               | Yes                     | ≤1          | Needles + Surgery tools + Discarded Gloves  |
| 16 | West Eye                  | Yes             | Yes               | Yes                     | ≤1          | Surgery supplies + petri dish, and etc...     |
| 17 | B&R Center                | Yes             | Yes               | Yes                     | ≤1          | Glove + Mask + Needle, and etc...            |
| 18 | Bakhshen                  | Yes             | Yes               | Yes                     | ≤1          | Surgery supplies + Needles + Test tube       |
| 19 | Zhyan                     | Yes             | Yes               | Yes                     | ≤1          | Bloody cotton + Needle + Surgical Waste      |
| 20 | Ashni Clinic              | Yes             | Yes               | Yes                     | ≤1          | Needle + Tube + General Waste + Expired dose |
| 21 | Xezani Tandrust Clinic    | Yes             | Yes               | Yes                     | ≤1          | Bandage + Needle + Sharp Knife               |
| 22 | Barzi Clinic              | Yes             | Yes               | Yes                     | ≤1          | Needles + General Waste + Expired dose       |
| 23 | Azmar Hospital            | Yes             | Yes               | Yes                     | 1           | Needles + Discarded gloves + Blood banks     |
| 24 | International Hospital    | Yes             | Yes               | Yes                     | 1           | Infectious waste + Regular Waste             |
| 25 | Harem Hospital            | Yes             | Yes               | Yes                     | ≥2          | Sharps + Needles + Bandages                  |
5. Conclusions

It concluded in this study, unfortunately, in Sulaimani city, there are many obvious reasons such as lacking environmental awareness among the public, and the solid waste generation varied during the four seasons of the year. The variation in the generation rate, varied and excuses for this variation clearly stated. Also, the clinic medical waste generation was also investigated for their constituents and quantity and also the possibility of its segregation and ways to dispose of it. All the clinics private and public ones were investigated and studied for having chimneys and the possibilities of air pollution due to the burning of the medical waste.

As a result, the Tanjaro dumping area became an ultimate place for all the types of waste generated in the city without any scientific treatment. Thus, air pollution occurring due to burning a portion of the waste is happening by irresponsible people, surface water pollution happening because of runoff the generated leachate out of waste composition process since the highest ratio of the household waste is organic waste in the city and it will affect the chemical structure of the water and threaten the survival of aquatic life of the river nearby. More agricultural land will be covered by uncontrollable dumping in the Tanjaro and it will affect the agricultural practices in the south of the city negatively. Soil contamination will happen due to dumping all these types of waste, including electronic and hazardous waste by household and industrial sectors. As a result, the chemical structure of the soil is changing (increasing the ratio of trace metals) and no longer can support any kind of cultivation. This study has inferred that the highest ratio of household waste in Sulaimani city is organic waste and then plastic waste. Besides that, according to the data collected from different stakeholders, it has shown that the ratio of the generated waste is changing from one zone to another zone in the city. Even the ratio of each type of waste was also changing and that was due to the fact that the lifestyle of the individual, the income of the family, the area of living and the level of education are all considered as main factors for that. Furthermore, this study has found that even waste generation inside the city will change according to the seasons. In some of the seasons like spring and summer, people generated more waste than the other two seasons. This was referred back to the fact that the majority of people staying at home during both seasons due to having summer holidays and other spring holidays.

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