American Journal of Biology and Natural Sciences
https://biojournals.us/index.php/AJBNS
ISSN: 2997-7185

Solid Waste Management and Treatment at Mosul University

Thair Yaser Suliman Hasan
University of Mosul/ College of Environmental Sciences/Department of Environmental Technologies

Hassan Alaa Shaker Jareeh
University of Al-Qadisiyah/ College of Science Department of Environment

Amjad Karim Kazem Attia, Ali Khalil Ibrahim Mumin, Osamah Maki Majed Hussain
University of Kufa/ College of Science /Environment Department

Received: 2024, 15, Sep
Accepted: 2024, 21, Sep
Published: 2024, 26, Oct

Annotation: Solid waste represents a real risk for people's health. Civilizations progress scale of their good management of solid waste. This project aims to evaluate Solid waste management of Mosul university. This research does not include demolition wastes at Mosul university due to war period. The results show that generation rate of S.W at Mosul university about 100 g/cap./d. The constituents of S.W is ranked as flows: organic matter, yard trimming, plastic, papers, glass, and Aluminum.

There are many suggested solutions to reduce the amount of the generated S. W; Converting the organic wastes to compost is the first, Size reduction of papers and volume reduction for each of plastic and aluminum materials is the second, finally, the incineration of unwanted materials.

It is vital to say; the application of the research's recommendations can be leads to lessen the efforts of municipal mangers.

Introduction:

Solid waste (S.W.) can be defined as all the different solid materials generated as a result of human use and which are disposed of because they are useless or excessive. As for solid waste management (S.W.M), it means the organized and purposeful control of each of the operating units associated with solid waste management from the point of generation to the final disposal site. Solid waste management goes through a number of main stages called functional elements and include the following (waste generation, storage, collection, transportation, treatment, recovery and finally disposal), as in Figure (1).

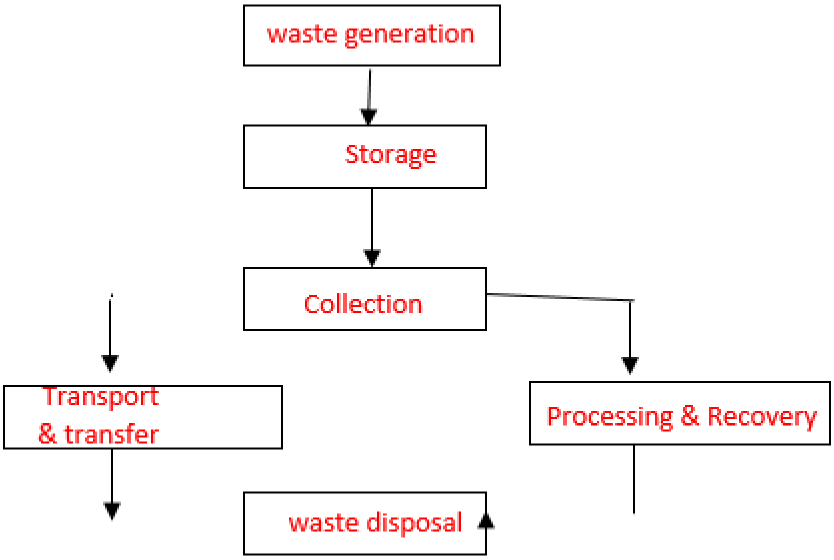

Figure (1) Stages of waste management

Types of solid waste:

1. Construction waste: Waste resulting from construction works.
2. Demolition waste: Waste resulting from demolition works.
3. Special waste: Waste from open areas, including street sweeping waste, dead animals, and unusable wheels.
4. Agricultural waste: Waste remaining from various agricultural works.
5. Hazardous waste: Chemical, biological, and radioactive waste that affects human, animal, or plant life immediately or its symptoms appear after a period of time. This waste may be liquid, solid, gaseous, or in the form of sludge or ash.
6. Household waste: (MSW) is household waste and may be organic or inorganic. It will be studied in this project.
7. Treatment plant sources: Solid or semi-solid waste resulting from water filtration or wastewater treatment plants.

Research objectives:

1. Calculate the total weight resulting from colleges, scientific departments, copying offices and cafeterias affiliated with them.
2. Find the percentage of each component of this waste.
3. Calculate the average amount of waste produced by each person daily based on the number of students in these units.

4. Explain the possibility of benefiting from some of the resulting waste such as paper, cardboard, plastic and aluminum by collecting them in special places and treating them within the university campus.
5. Explain the possibility of benefiting from organic waste and tree leaves in producing organic fertilizer for university gardens.

Methodology:

Study Area:

The study is located in the University of Mosul, which has an area of (93.86) hectares as shown in Figure (3). The number of students, teaching staff and employees exceeds 35,000 students and employees.

The study included a large number of colleges and departments, in addition to the central library and other service buildings such as the student center, the environmental research center, the computer center and the internal departments, as shown in Table 2.

Figure (3) University of Mosul website

Previous studies:

There are many local studies that were conducted on the composition of solid waste in the city of Mosul and the statement of its generation rate. We mention some of them: (Al-Rawi, Sateh Mahmoud and Al-Tayyar, Taha Ahmed, 2012) studied the composition of waste and calculated its generation rate in the city of Mosul. The results showed that organic waste reached 68% and the percentage of materials that can be recycled was 20% and the rest is not recyclable. The results also showed that the average production of one person from total waste reached 0.61 kg specified daily.

(Al-Watar, Abi Muhammad Sabri and Mahmoud, Sahar Abdul Jawad, 2012) concluded that the city of Mosul produced 620 tons of solid waste daily in 2008 and that more than 80% of it was organic waste. The research concluded that the Mosul Municipality Directorate can establish a compost station with a design capacity equivalent to 1000 tons of organic fertilizer by making use of organic waste.

Methods of solid waste treatment:

There are several ways through which we can treat the waste problem, and each of the mentioned methods has advantages and disadvantages, as it depends on the type of waste disposed of and the conditions available for each method of treatment. The importance of treatment is graded as in Figure (4), which shows that one of the first priorities of treatment is reducing sources, which comes at the top of the pyramid, followed by recycling, then burning, and finally landfilling. The following is a brief overview of each method:

Figure (4) Solid waste treatment priorities

Source Reduction:

Reducing sources from their source is one of the most important methods that must be followed in addressing the waste problem. It is considered the goal in many developed countries, where containers of different colors are placed in front of each house and shop, symbolizing each type of waste, such as paper, in special containers, aluminum cans in a container, and organic materials in special containers, and so on. Thus, each component of the waste is removed by the specialized companies, and sometimes incentive amounts are paid by the company for each weight of this waste, especially the valuable ones.

Recycling:

Recycling is considered one of the ideal methods for treating waste after reducing sources, as it protects natural resources, reduces the volume of waste, and creates new job opportunities, in addition to ridding the environment of some waste that is resistant to decomposition, such as plastic and tires. The individual may not achieve direct results if he contributes to sorting his waste, but the citizen will benefit indirectly, as recycling waste allows the recovery of part of the amounts allocated to purchase these goods by recycling aluminum cans, paper, plastic, etc. The following is a mention of the advantages and disadvantages of recycling some waste.

Landfill:

It means the process of dumping, compacting and covering the waste with a layer of soil at the end of each working day in order to dispose of household waste. The waste is received daily and spread out on site and compacted in cells 3 m long and 3 m high (including the thickness of the soil layer) and covered with a layer of impermeable soil with a thickness of not less than 25 cm at the end of the day. This lifting of the compacted waste with the cover layer is called a cell. As in Figures (6 & 7), there can be more than one elevation, but it is preferable that it does not exceed three elevations. After the area designated for burial is filled, the upper cells are covered with a final top layer of impermeable soil with a thickness of not less than 50 cm after the tamping, taking into account the work of shedding it from both sides to prevent rainwater from standing on it, taking into account the periodic maintenance of the depressions that occur and not building on them in the future, but it can become a green area or a playground. After burying the waste and with the passage of time, the concentration of organic materials in the filtered leachate decreases, while the concentration of ammonia will increase, and recycling the leachate will also increase ammonia and reduce its carbon content.

Advantages and disadvantages of sanitary landfilling of solid waste: It is known that each treatment method has disadvantages and advantages that depend on the type of waste, landfill site, prevailing conditions and land uses, as in Table (2).

Table (2) Advantages and disadvantages of sanitary landfill

No.	Advantages of sanitary landfill	Disadvantages of sanitary landfill
1	It is economical if land is available.	It is not economical if suitable land is not available.
2	Its initial cost is low.	Need to monitor its operations from sieving and covering waste.
3	The waste does not require additional treatment such as fermentation or incineration.	People do not like having a sanitary landfill near their homes.
4	Its operations are flexible as it has the ability to receive any amount of waste.	It needs continuous maintenance due to the constant depressions that occur in it.
5	The resulting biogas can be used to produce energy.	It cannot be built upon in the future.

Selecting the appropriate sanitary landfill site (Site selection):

1. Availability of land: An area of land should be allocated sufficient to bury household waste for at least one year.
2. Collection distance: When choosing the landfill site, we try not to make the waste transport distance too far from it, and the landfill site is often designed at a distance of 16 km outside the city.
3. Soil and topographic conditions: A site should be chosen with impermeable soil suitable for daily burial and burying the last layer.
4. Weather conditions: The direction of the prevailing wind should be taken into consideration so that the direction of the prevailing wind does not pass over the landfill area first and then the city.
5. Surface water hydrology: The paths of surface water should be known so that they do not conflict with the landfill site.

Landfilling methods and operation:

There are several methods used for sanitary landfilling (depending on the type of soil available and the presence of groundwater) as follows:

1. Area method: This method is used when the available soil is not suitable for landfilling, so the soil must be scraped and replaced with impermeable soil by bringing soil from another suitable area. It also requires continuous soil for daily landfilling and final cover. This process is usually expensive and is only used in special cases.
2. Ramp method: This method is used when the available soil is suitable for landfilling, so there is no need to scrape and replace the soil, but rather just roll it up and start the rest of the landfilling operations. It is called a roll because the converted accumulated waste (cell) is placed above the ground, pushed and leveled in the form of ramps.
3. Trench method: This method is used when the available soil is suitable for landfilling, but the groundwater level is close to the surface, so a hole is dug to the dimensions of the cell and then filled with waste and rolled up, and a hole is not made It is left for a long time so as not to give the groundwater time to come out. After completing the first cell, the next cell is dug and the soil coming out of it is thrown as a cover for the cell that precedes it, and so on.

Processes that occur after the end of the burial process:

1. Period of reproduction and growth of aerobic bacteria: This is due to the availability of conditions of food and confined oxygen.

2. Transitional period: In which aerobic processes are transformed into anaerobic processes as a result of the depletion of oxygen and the death of aerobic bacteria to be replaced by anaerobic and facultative bacteria.

3. Period of formation of volatile organic acids: As all anaerobic reactions begin with the decomposition of organic materials and the formation of complex acids, and then the components of simple acids are decomposed, and this stage is often accompanied by a decrease in the value of the acid function due to the increase in methanogenic bacteria that feed on these acids.

4. Period of formation of methane gas: As the production of methane gas increases due to methanogenic bacteria, carbon dioxide and hydrogen sulfide are also produced.

5. Aging period: In which nutrients decrease after a long period of time and the activities of microorganisms decrease with it, thus the generation of methane gas decreases and most of the buried organic materials are converted into their primary elements.

Fermentation:

Organic waste is the largest part of solid household waste and may reach 80% of total household waste in some cities. It consists of sugars, cellulosic and semi-cellulosic materials, fats, esters, amino acids and proteins in addition to lignin, the composition of which is not known yet. The crushed organic waste is placed in long rows called composting piles, where garden waste is piled up with household waste. The height of each row is 2 m and its width is 4 m and its length may reach tens of meters. Sludge may be added to it to accelerate the decomposition process. The fermentation process is a process that depends on aerobic bacteria, actinomycetes, algae and protozoa in the decomposition process and therefore requires continuous stirring to provide the oxygen necessary for the decomposition process. The final products remaining after the fermentation process are soil conditioning materials called humus as shown in Figure (8). The humus is characterized by the following specifications: its color is dark brown, tending to black, and it has a soily smell. It has a composition that varies continuously depending on the activities of microorganisms. Finally, it has a low ratio (carbon to nitrogen) due to the high availability of nitrogen in it, which is necessary for building the cells of living organisms. The amount of compost added to cultivated soil ranges from 30 to 120 tons per hectare per year.

Figure (8) Is a picture of Compost.

Calculations and results:

Calculating the daily weight of the main units:

Samples were taken from the waste generated by the colleges, departments, cafeterias and copying offices at the University of Mosul, and then all the weekly collected waste for each unit was weighed as in Table No. (3).

Table No. (3) Weekly accumulated weight of waste in each unit

No.	Colleges	Weekly accumulated weight	Daily weight (kg)
1	Pharmacy	290	58
2	dentistry	330	66
3	Veterinary medicine	360	72
4	Engineering in all its departments	456	91
5	Sciences in all its branches	550	110
6	Faculty of Environment	96	19
7	Education in all its sections	658	132
8	Literature	597	120
9	Management and Economics	510	102
10	Agriculture and forestry in all its sections	889	178
	Physical education includes all its sections	1200	240
	Centers		
1	Student Center	620	124
2	Environmental Research Center	297	60
3	Computer Center	288	58
	Private buildings		
1	Internal sections	1655	331
2	University Stadium	2698	540
3	Cafeterias for all departments	1220	244
4	Copying offices	888	178
5	University Mosque	120	24
	Special waste (street sweeping, tree trimming, lawn mowing, etc.)	4200	840
	the total	17,922	3585

Calculating the percentage of each component of the waste:

The percentage of each component of the waste was calculated after sorting the components and then dividing the weight of that component by the total weight discarded daily, calculated as a percentage as in Table (4).

Table (4) Percentage of components

Components	Daily ingredient weight	Percentage
Organic waste	1972/3585	55%
Plastic	430/3585	12%
Paper	395/3585	11%
Minerals	251/3585	7%
Tissues	72/3585	2%
Garden and private waste	840/3585	23%
glass	72/3585	2%

Calculating the waste generation rate:

Total weight 17,922 kg per week, which represents five days at the university

Daily waste weight 3585 kg/day

Waste generation rate = Daily waste weight / Number of students and affiliates

Generation rate = 3585/36,000= 0.0995 kg=100 g/cap. /d

Calculating the waste density and its daily generated volume:

The density of the waste was calculated by taking a container of a known volume as in Figure (10) and the density was measured by taking the dimensions of the container and then filling it with mixed wet waste, where the weight of the container with the waste was taken, where the density = waste mass / volume.

Figure (10) is a picture of the cylinder used to measure the density of waste.

The results showed that the waste density of some main waste components was as shown in Table (5).

Table (5) Unlimited density of some generated components	
Source	Range (kg/m^3)
inorganic waste	110
Weeds and garden debris	90
Garbage (food scraps)	520
Average	240

The results showed that the average waste density = 240 kg / m3

The total volume of waste disposed daily 3585/240 = 14.93 m3 = 15 m3 per day

Estimating the number of wheels required to transport waste:

Since the weight of waste disposed daily is approximately 3585 kg and the source of waste generation is different locations, i.e. not in one or two locations that can be lifted by large wheels (tippers), it is better to lift the daily waste using wheels designated for the university and in a small size such as a tractor and special workers with each wheel.

Since the average dimensions of the cart pulled by the tractor are (2.5*1.5*1) meters, i.e. a volume of 3.75 cubic meters, the number of small wheels required is 15/3.75) i.e. approximately four wheels that can be distributed as follows: two wheels if the two wheels work three trips per day due to the short distance of transportation within the university campus and a spare wheel, and each wheel is assigned three workers with the driver to lift the waste, i.e. six workers. The fourth wheel is dedicated to transporting only organic waste from restaurants, cafeterias, garden waste and paper to the proposed fermentation site if it is established within the university campus.

Moisture content of waste:

The moisture content of waste was calculated using the wet method as in the following equation:

W = (A-B) * 100/A

Where W means the moisture content of waste calculated as a percentage

A is the wet weight of waste

B is the dry weight of waste

As for the method of work, a sample of the mixed waste was taken in a small container and its wet weight was taken, then it was dried and its dry weight was taken.

The results showed that the moisture content of the waste was 22%.

Calculations of materials used in compost production:

We assume that the materials used in compost production within the university campus consist of the following materials, Table (6):

Organic waste (restaurant and cafeteria waste) = 244 kg -1

Weeds cut from university gardens = 520 kg/day -2

Leaves = .11*40 = 440 kg/day -3

Tree leaves = 0.2*4 = 800 kg -4

Table (6) The percentage of nitrogen and carbon in waste

The material	Nitrogen%	carbon %	Quantity
paper	0.04	25	395 kg
Organic waste	3	30	1972 kg
Garden waste	1	50	840 kg
the total			3207 kg

C=0.395*25 +1.972*0.3 + 0.840*50 =52.5 ton

N= 0.395*0.04 +0.1970*3 + 0.825*1 =1.43 ton

C/N=52.5/1.43= 36.7

It is a mixture close to the ideal for producing compost, as the ideal mixture ranges from 25:1 to 35:1. More nitrogenous materials can be added to bring the ratio closer to the ideal, such as adding sludge resulting from liquefaction stations.

The materials used in compost production daily = 3.5 tons

Since the components used decrease as a result of decomposition, transformation, and interference with grinding and homogenization to less than half

Thus, daily compost can be produced estimated at one and a half tons per day = 1.75 tons

Noting that compost is distributed at a rate of 30-120 tons per hectare per year

Since the area of university gardens = 30 hectares = 30,000 m2

30*30=900 tons per year, the gardens need the minimum value.

The annual production rate = 1.75*365=638 tons.

That is, the output is approximately sufficient for two-thirds of the quantity required for university gardens.

Calculating the surface area of the components of the fermentation and collection sheds and accessories:

The fermentation shed needs a pre-equipped shed with a waste threshing machine that is sufficient to receive the daily generated waste with an area of not less than 300 m2.

As for the fermentation shed, it must have a large area sufficient to receive and collect the generated waste for at least two months and is equipped with sprinklers and a fermentation column stirring device with an area of not less than 2500 m2 and a height of 10 m.

Thus, the total area of the required canopy is 2800

The workplace needs gardens, yards and service buildings equivalent to the area of the canopies, so the total area required is (2500 + 300) * 2 = 5600 square meters

Calculating the potential energy of the generated waste:

The potential energy of the waste can be calculated according to the method of Khan (Khan, 1991), as this equation enables us to calculate the maximum calorific value after knowing the percentages of the components as follows:

HHV(KJ/kg) = 53.5 (F + 3.6 CP) + 372 PLR

F: represents the mass percentage of food waste

CP: represents the mass percentage of cardboard and paper waste

PLR: represents the mass percentage of plastic, rubber and leather waste

The results showed that the maximum calorific value of the waste recorded in Table (7) for each kg of waste is 9.998 million joules/kg calculated as one million joules.

Table (7) The percentage of components included in calculating the maximum thermal energy of waste according to the Kahn method

Paper %	Metals %	Glass %	Food %	Plastic, rubber and leather, PLR %
11	7	18	55	12

HHV=58.5 (55+3.6*11)+372*12=9998 kj/kg= 9.998 Mj/kg = 10 Mj/kg

Calculating the minimum calorific value of waste LHV:

It is worth noting that the net energy is the one used in calculating the latent energy, as the minimum calorific value equals the maximum calorific value minus the energy of evaporation water as in the following equation LHV=HHV-Ql, noting that the energy of evaporation water Ql can be calculated from the following equation: Ql=2440(W+9H)

Ql: Latent heat of lost water vapor (kilojoules/kg)

W: Weight of moisture in the waste (kg)

H: Weight of hydrogen in dry waste (kg)

Since the moisture content of the waste was 22%, and if we assume that 6% of the dry weight of the waste is hydrogen, then the minimum calorific value of the waste isQl=2440(0.22+9*(1-0.22) *(0.06)) =1564 Kj/kg

LHV= HHV-Ql, LHV=9998-1564=8433 kj/kg =8.4 Mj/kg

Conclusions:

1. Daily waste disposal rate per person within the campus: 100 gm/day
2. Percentage of organic waste rate from total waste: 55%
3. Percentage of paper within the waste: 11%.
4. Percentage of plastic waste: 12%.
5. Percentage of garden waste: 23%.
6. The results showed that the average waste density: 240 kg/m3.
7. Total volume of waste disposed daily: 15 m3 per day.

8. Number of wheels required to transport waste daily: 4 tractor size with three trips per day.
9. Moisture content of waste: 22%.
10. Daily compost production estimated at one and a half tons per day: 1.75 tons.
11. Estimated area allocated for fermentation works: 5600 square meters
12. Estimated net potential energy of inorganic waste that can be used in incineration: 8.4Mj/kg

References

1- Youssef Mohamed Hamada Abdel Rahman (2004) "Recycling of plant waste". Central Laboratory for Design and Statistical Analysis Research - Agricultural Research Center, Egypt

2- Dr. Walid Al-Qaw Sami. "Manufacturing compost from organic waste". Agricultural Extension Publications - Ministry of Agriculture – Jordan

3- Article (20) of the Jordanian Interim Agriculture Law No. (44) of (2002) "Instructions on the conditions of licensing for the production, preparation, storage, circulation, trade and advertising of fertilizers and plant growth regulators".

4- Abu Rawida, Abdullah Salim and Al-Taher, Imad Al-Din (2003) Solid Waste Management and Recycling in the United Arab Emirates - Reality and Ambition, General Secretariat of Municipalities, Dubai.

5- Khorshid, Hisham Tawfiq Jamil, (2010) Solid household waste in the city of Baqubah and the possibility of treatment by recycling industry, Master's thesis submitted to the College of Education, Al-Asma'i, University of Diyala, unpublished.

6- Al-Qader, Aj'eer Abdul (2002) The Moroccan experience in the field of solid waste management and recycling, State Secretariat for the Environment, Kingdom of Morocco.

7- Al-Tayyar, Taha Ahmed and Al-Rawi, Sateh Mahmoud (2012) "Composition and productivity of solid waste in the city of Mosul, a comparison between two decades" Tikrit Journal of Engineering Sciences, Volume 19, Issue 1, Page No. (05-43). 8- Al-Watar, Abi Muhammad Sabry and Mahmoud, Sahar Abdul-Jabbar (2012) "The possibility of recycling solid residential waste in the city of Mosul" Rafidain Development Journal. Volume 109 / Issue 34 / Page 10-26.

8- Hamad, Ammar Thamer and Suleiman, Fadia Abdul-Qader (2016) "Finding quantities and determining the characteristics of solid household waste disposed in the city of Mosul" Tikrit Journal of Engineering Sciences. Volume 23, Issue 4. Page No. 103-108.

9- Al-Naama, Ayad Fadhil and Sabry Rasha and Muzaffar Ru'a (2014) "Solid waste treatment at the University of Mosul, unpublished data.

10- Ahmed, Muhammad Fakhr al-Din (2019), "Lectures on solid waste" Department of Environmental Technology, College of Environmental Sciences and Technologies, Department of Environmental Technology.