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# Waste Recycling: Waste to Energy System

Basheer Abdulrazzak Ghani
*Al - Mustansiriya University , college of engineering , department of mechanic , Baghdad , Iraq*

Nadhim Mejbil Faleh
*Al - Mustansiriya University , college of engineering , department of mechanic , Baghdad , Iraq*

ORIGINAL STUDY

# Waste Recycling: Waste to Energy System

Basheer A. Ghani*, Nadhim M. Faleh

Al - Mustansiriya University, College of Engineering, Department of Mechanic, Baghdad, Iraq

**Abstract**

**The current economic growth trend of increased urbanization has resulted in huge amounts of municipal waste and energy consumption. Many emerging countries, such as Iraq, suffer from the worsening of such a problem. Thus, an adequate municipal waste management system and the innovation of renewable energy alternatives are the fundamental issues that need to be addressed.**

**Two test rigs were used in this study: the first separates waste based on the principle of gravity and the difference in density between the constituent elements of the waste, The test rig consists of a conveyor belt (0.5 m) width and (1.5 m) length with variable height and speed that throws the waste into special containers to separate the waste. The study suggested taking samples of equal size (1 cm3) for all elements and showing the effect of the sampling process on the separation methods approved by the test rig. The second is a laboratory test rig that analyzes waste and produces combustible gas, thus producing thermal energy. The main components of the rig are a digester (0.4 m diameter - 0.64 m height), a calorimeter, and several other components.**

**The data analysis method developed by Japanese scientist Takeuchi was used to analyze the results of the first test rig's experimental work. The main results of this analysis showed that the height is (0.67 m), the speed is (1.9 m/s), and the distance of the samples falling ranges from about (0.53 m) to (0.58 m).**

**The significant findings of the current study for the second test rig are obtained for the amount of thermal energy and measured using a calorimeter, and it was found that the highest value of energy was obtained on the 23 day of the start of the fermentation process; the amount was (10752.88 Jules) in the second experimental test.**

*Keywords:* Waste separation machine, Waste-to-Energy, Solid waste, Automatic separation process, Anaerobic digestion, Solid fuel combustion

## 1. Introduction

The current increase in solid waste generation, as well as the major problems in handling this trash, is risking worldwide development, especially in newly-visible nations. In a business-as-usual picture/situation, around 2 billion tons of city-based solid trash (City-based garbage) is created around the world each year, and this amount is expected/looked ahead to rise by nearly 65 percent to 3.4 billion tons by 2050 [1]. This problem also presents an opportunity: city-based garbage is plentiful, especially in consumer-oriented nations, and might be a money-making product under some conditions. It possesses a high proportion of biogenic carbon (50—60%) and a high energy content, pointing to showing its strong possible ability to be a renewable energy source [2]. City-based garbage has chemical energy that may be changed into a variety of energy sources, including heat and electricity. This procedure is generally carried out using one of two methods: heat or biochemical treatments [3]. Warm and organic treatment advancements for civil trash have grown rapidly to transform huge measures of extra metropolitan waste into helpful products. waste-to-Energy (WtE) power plants are a potential warm transformation innovation that might be utilized to consume civil rubbish-based materials streams, bringing down ozone-depleting substance outflows and lessening how much land is required for metropolitan garbage removal. Simultaneously, the power meeting the developing worldwide

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* Corresponding author.
E-mail address: ehma008@uomustansiriyah.edu.iq (B.A. Ghani).

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requirement for electricity creates is utilized. As indicated by the latest report from the Unified Countries Modern Improvement Association [4]. Human activities (modern, family, business, and working) as well as creatures make such trash in different ways. A portion of the trash created by economic activities can't be reused. In the event that not tended to, a large portion of these squanders can hurt the environment and cause contamination, which straightforwardly corresponds to populace development. This figure featured a tremendous issue standing up to the globe, specifically, the deficiency of 10% of human existence inferable from waste-related infection [5]. Besides, it is observable that inappropriate waste administration dirties the air, water, and land. Moreover, the waste classifications in Baghdad are displayed in Fig. (1). Accordingly, a definitive objective of such measures is to guarantee practical development and great waste administration to diminish the effect on people and the climate [6].

"Reuse, Reuse, and Recuperate" are the most central solutions for diminishing strong waste, though waste entombment is a definitive choice [7]. Squander that is left disregarded affects the climate and should be controlled. Whether or not a nation is created or created, squandering the executives has forever been a troublesome errand for all intents and purposes of each region in the world. Different human activation at the home grown, business, rural, and modern levels bring about garbage, which is both natural and inorganic in nature. In nature, in light of the substance and wellspring of the age [8]. however, In Iraq, it is usually alluded to as garbage or waste, and it is created by houses, work environments, inns, eateries, commercial centres, business buildings, and establishments, among different spots. Bundling, strong and non-sturdy things, yard trash, and strong and semi-strong kitchen squander make up most of it. Due to the previously mentioned causes, a lot of junk is likewise unloaded openly on free land in Iraq without being dealt with. In Baghdad, trash is covered in landfills in the Al-Nabai and Nahrawan locales, and there is no committed station for dedicated sorting and treatment before entombment Quick development in trash creation is putting a weight on Iraq's waste administration foundation, which has been gravely harmed by many years of mismanagement. Most squanders are tossed in uncontrolled landfills across Iraq because of an absence of present-day and viable waste administration and removal framework, with practically no respect for human wellbeing or the climate. Unconstrained flames, surface water contamination, groundwater defilement, and enormous scope greenhouse gas discharges have been the signs of Iraqi landfills [9]. However, MWM in industrialized countries differs in a number of respects, including source segregation, suitable waste processing technology, and the confinement of landfill disposal to inert and non-recyclable waste. When selecting a waste processing technology, the waste composition is a crucial factor. It must thus be carefully examined. Common waste processing techniques include anaerobic digestion (AD), combustion, incineration, and composting [10].

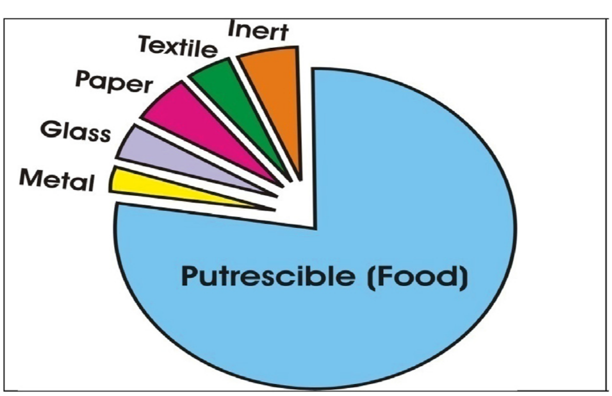


*Fig. 1. Components of municipal solid waste as weight percent in Baghdad city [6].*

## 2. Methodology

The comparison of the two primary waste-to-energy technologies, anaerobic digestion and WTE combustion, as non-recycled waste disposal alternatives in Iraq-Baghdad, was the main objective of the study. In this study, the researcher used a two-part methodology that included an expert survey and data analysis. The goal of the literature review was to get more knowledge about WTE technology, municipal waste management, and its applications. Additionally, the literature review provides information on the state of WTE technologies at the moment, as well as economic and environmental aspects to take into account when making a judgment. Prior to deciding on an adequate process for turning trash into energy, which is in and of itself a difficulty, it is important to establish a suitable system for segregating municipal garbage. Fig. (2) displays the conceptual framework.

## 3. Waste-to-energy systems

Incineration technology, which was invented for the first time in history in Denmark in 1903, was the precursor to WtE technology. The two most widely utilized processes for turning municipal garbage

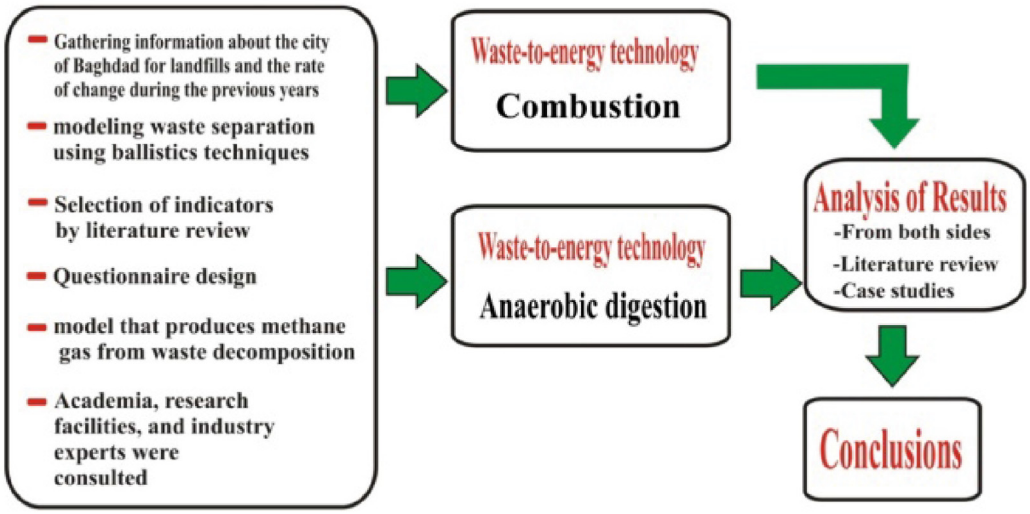


*Fig. 2. Methodological overview.*

into energy are thermal treatment technology (thermochemical conversion) and biological treatment technology (biochemical conversion). For trash with low moisture content, thermochemical conversion is preferable; for waste with high moisture content, such as organic waste, biochemical conversion is preferable. The different waste conversion procedures are depicted in the flow chart Fig. (3) below [11]. The energy that is recovered from waste can be used to provide power, heat, or both (commonly referred to as combined heat and power). How potential end users intend to use the available heat and/or electricity will decide the energy source that is chosen [12]. moreover, Energy recovery, which is carried out by either burning or anaerobic digestion of municipal garbage and is the most ecologically benign option, is a crucial part of waste management. Combustion or digestion of municipal refuse reduces waste while generating electricity. Replacing fossil fuels with renewable energy, this technique lowers greenhouse gas emissions and the generation of methane in landfills. By employing the proper WtE technology, reducing the volume of municipal waste, and producing energy, it is possible to use municipal trash in this situation to recover energy. It lessens greenhouse gas emissions from open dumping and landfills, assisting in the resolution of the issue of a limited amount of landfill space [11].

One of the techniques for producing energy from waste is combustion. Combustion is the process of burning municipal waste in its raw form to produce energy in the form of heat or electricity. At a temperature of 850 °C, the waste must be effectively oxidized by the combustion process in order to be converted to carbon dioxide and water [11]. The method of turning rubbish into energy by burning waste in an electrical station outfitted for a full investigation is shown in Fig. (4). Energy recovery by incineration is a well-known and superior method of handling municipal waste in big cities that helps reduce the quantity of waste that is

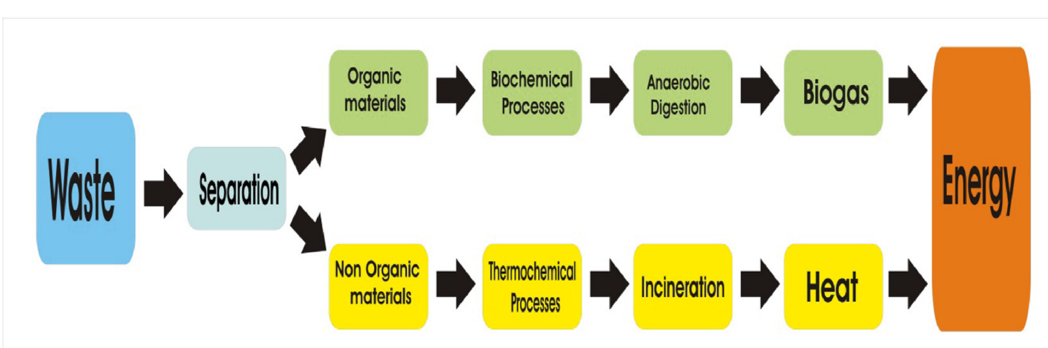


*Fig. 3. Waste to Energy technologies.*

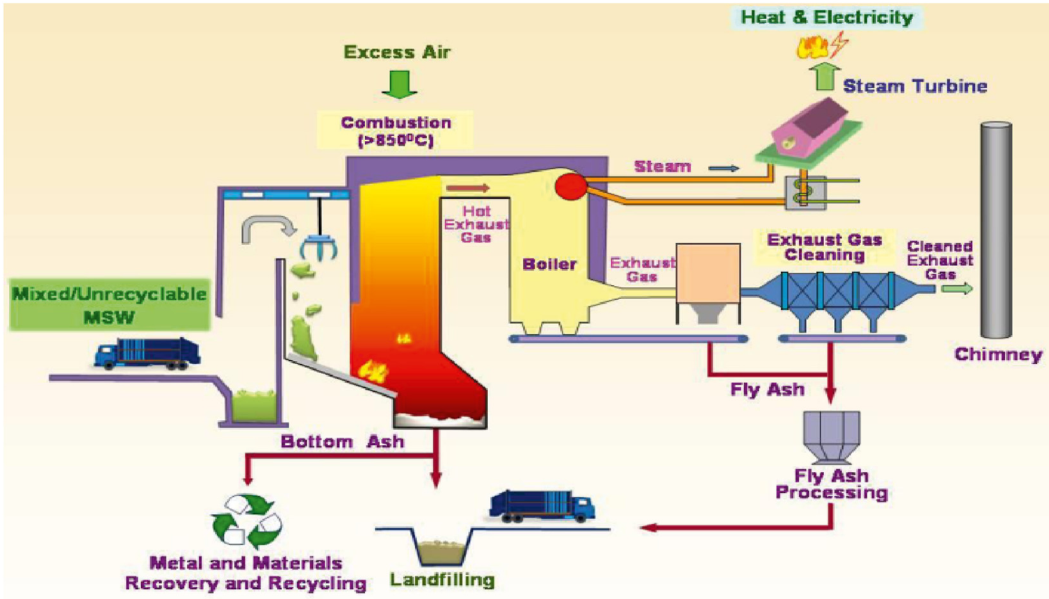


*Fig. 4. Incineration flow chart which shows the thermal treatment technology [11].*

landfilled. This approach looks to be feasible in an urban setting, offering a practical choice for controlling significant amounts of municipal waste while simultaneously recouping energy. However, this technique requires a substantial investment since environmental safeguards must be taken to reduce emissions. Therefore, before incineration technology is used, it is important to take into account factors such as waste volume, waste combustion heat, location, maintained facilities, operation and maintenance expenses, and investment. Additionally, most developing countries dislike.

### 3.1. Anaerobic digestion

Anaerobic digestion is a complex biochemical process in which a large number of facultative and anaerobic microorganisms simultaneously consume and degrade organic materials. As a result of its inherent energy efficiency and frequently minimal chemical requirements, anaerobic digestion is the stabilization method that is most frequently utilized in medium and large municipal solid waste plants. As shown in Fig. (5), anaerobic bacteria stabilize the organic waste during anaerobic digestion in airtight tanks, where they also release $CO_2$ and methane. The digested sludge is suitable for soil conditioning since it is pathogen-free, non-aggressive, and stable. Anaerobic treatment has the benefit of achieving high levels of stability while minimizing the biological degradation of organics [14]. The calorimeter includes a manual stirring arm that is submerged in the water and an electronic thermometer that is attached to a glass container that is filled with water and suspended by a bearing above the combustion chamber. Fiberglas is used to insulate the glass container's surroundings from heat. The law below is then employed to determine the quantity of latent heat after reading the water temperatures before and after the gas-burning process. Understanding how much energy is produced by waste fermentation for every kilogram of organic waste.

$$q = C_v\,(T_f - T_i)$$

$$q = S\,m\,(T_f - T_i) \ [15] \tag{1}$$

where:

q = is the amount of heat (j).
S = specific heat (j/g c°) = 4.184 j/gc° for water.
m = mass (g).
Tf = final temperature.
Ti = initial temperature.

### 3.2. Separation procedure

After defining the issue, a gravity separation strategy was used, which separates materials based on differences in specific gravity (SG) across various

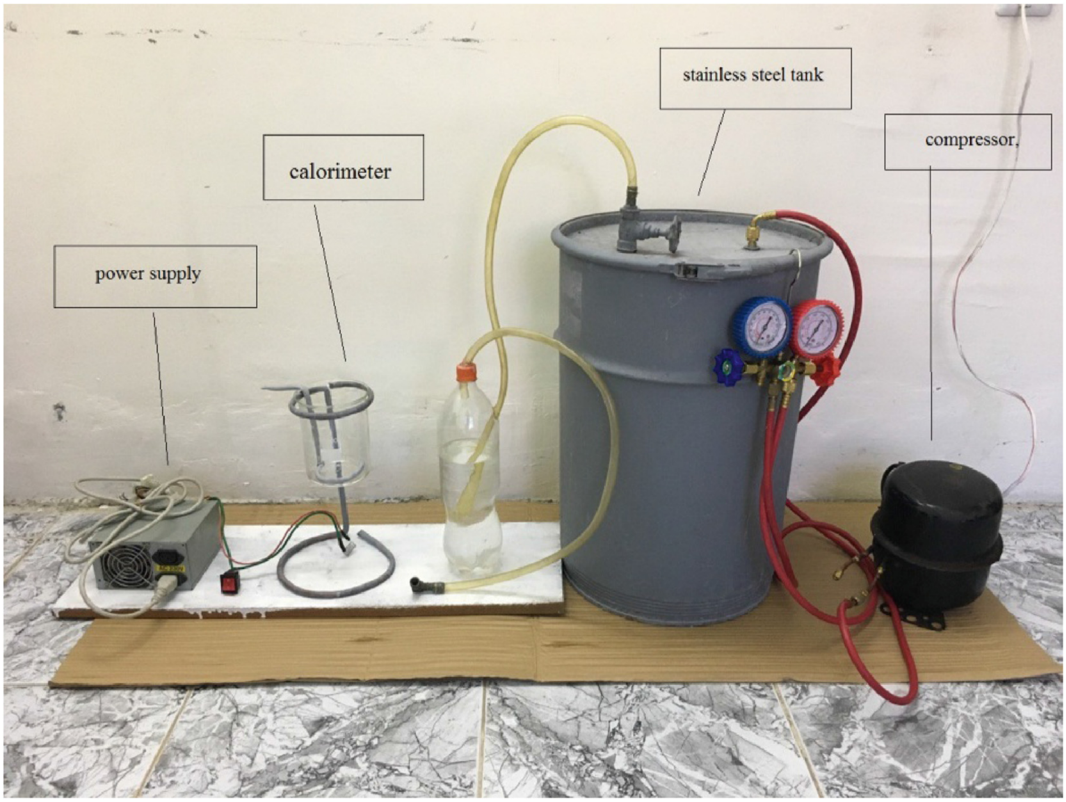


*Fig. 5. Anaerobic digester Rig.*

minerals. Despite the fact that there are separators for dry gravity instances, this method involves wet work. Gravity separation is successful when the SG of the materials that need to be separated changes significantly. Additionally, the particles have a square structure and a steady, moderate particle size. Under specific operating conditions, the experiments in this study are designed to produce separation applications. This study used a local analysis to try to find the relative composite fraction in Baghdad rubbish. Aluminium cans made up 34% of the rubbish, followed by plastic (52%), while paper, dust, and other materials made up the remaining [5]. Storage box, transporter belt, electric motor, clamping rollers, accelerometer, separation containers, and camera make up the system shown in Fig. (6). When the garbage is deposited in the storage box and moved equally by gravity to the transporter belt, and is then assigned a speed and linear acceleration that are both equal to the speed With containers positioned at various distances from the transporter belt, trash is thrown at varying distances depending on the mass density of the material by the acceleration of the transporter belt, whose speed is regulated by the electric motor and the accelerometer.

## 4. Design

### *4.1. Design of the transporter belt*

The transporter belt has been designed particularly for flat idlers. The load stream area, or cross-sectional area of the load on the belt, is calculated using

$$A = 0.16B^2 \text{ C} \tan \text{Ø} \ [16] \quad (2)$$

Where, B = the width of the belt which is selected to have a value of 500 mm. C = a constant with a value between 0.85 and 1.00. A value of 1.00 is selected.

Ø = 0.35 × static angel of response of load [16].

Municipal solid trash is classified as refuse because it is slow in terms of flow ability, abrasive, and very light and fluffy, which means it may be blown around. As a result, the static angle of repose is 40° and upward. A 45° angle has been chosen. Thus,

$$Ø = 0.35 \times 45 = 15.75.$$

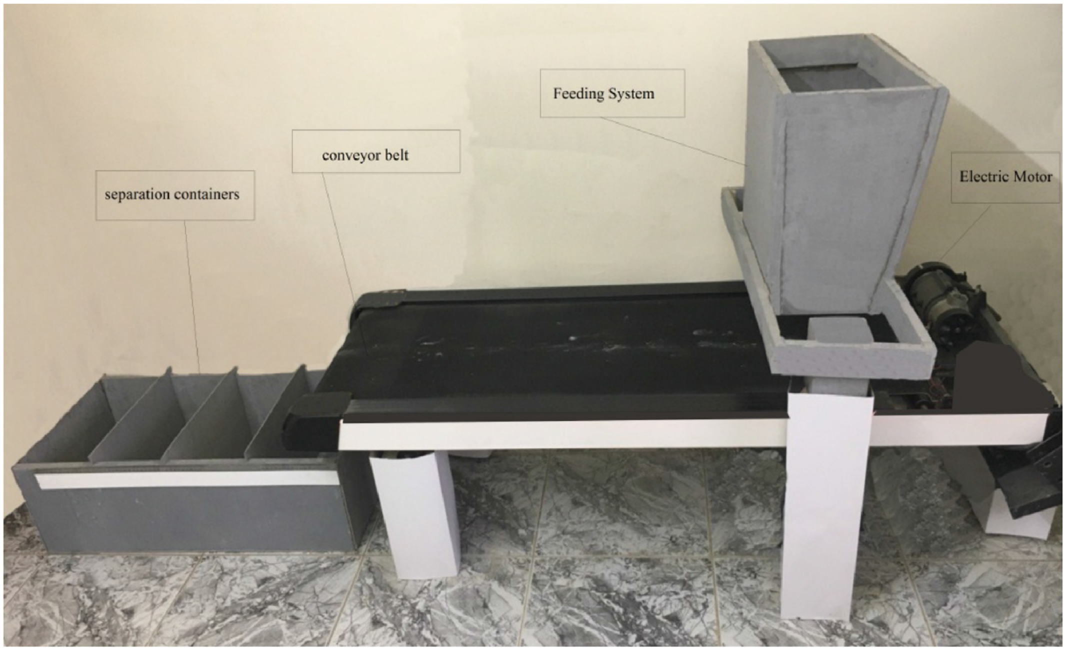


*Fig. 6. Separation rig.*

Therefore, the cross sectional area of load on the belt is.

$$A = 0.16 \times 0.5^2 \times 1 \times \tan 15.75 = 0.01128\ m^2$$

The capacity of the transporting is estimated using

$$Q = 3600\ A\upsilon\gamma\ [16] \qquad (3)$$

Where

$\upsilon$ = Transportation speed which should range from 0.5 to 0.8 m/s

a speed of 0.7 m/s selected

$\gamma$ = specific weight of the load in $KN/m^3 = \rho g$

$\rho$ = Density in $kg/m^3$

g = Acceleration due to gravity = $9.81\ m/s^2$

The typical density of refuse is 160–320 $kg/m^3$ [16]. Uncompacted and compacted solid wastes had similar densities of 140.5 $kg/m^3$ and 223 $kg/m^3$, respectively. However, for the design, a value of 300 $kg/m^3$ was used. As a result, the municipal waste's specific weight is

$$\gamma = 300 \times 9.81 = 2.94\ kN/m^3$$

Hence, the capacity of the transporting is.

$$Q = 3600 \times 0.01128 \times 0.7 \times 2.94 = 83\ KN/hr$$

The nominal volume capacity is estimated using [16]:

$$V = 3600 \times \text{load stream area} \times \text{belt speed} = Q/\gamma \quad (4)$$

$$V = 28.42\ m^3/hr$$

*4.2. Design for transporter Pulleys and Shafts*

The diameter of the transporter pulley drum, D, has been chosen to be 100 mm for the belt width chosen and to have a face width of roughly 600 mm for an edge clearance of about 50 mm. The pulley's rotating speed, and therefore the shaft's speed, which determines the transporter belt's chosen translational speed, is calculated as.

$$N = 60\ \upsilon / \pi\ D = 60 \times 0.7 / \pi \times 0.1 = 133.69\ rpm \quad (5)$$

The full thickness longitudinal tensile strength is selected as 160 kN/m [16]. For a belt width of 500 mm, the tensile force in the belt is

$$F = 160 \times 0.5 = 80\ KN$$

The permissible or working tension, Fall, on the transporter belt is 8 kN, assuming a factor of safety of 4 for material subject to unpredictable stresses and loads. The torque generated by this force around the 100 mm diameter pulley is.

$T = B \times 0.1/2 = 0.4$ KN.

The power to be delivered to the transporter belt through the pulley is

$$P = F \times \upsilon = 8 \times 0.7 = 5.6 \text{ KW} \quad (6)$$

The diameter of the shaft to drive the transporter belt is estimated as

$$D = \left(\frac{16\, Tn}{\pi\, \tau}\right)^{\frac{1}{3}} \quad (7)$$

Where $\tau$ is the maximum allowable shear stress, taken as 55 $MN/m^2$ for commercial steel shafting [16]. Hence.

$$D = \left(\frac{16 \times 400}{\pi \times 55 \times 10^6}\right)^{\frac{1}{3}} = 0.0333\text{m}$$

The shaft diameter selected is thus 35 mm for the driver and driven shafts.

## 5. Results

### 5.1. Results of Separation Rig

When the transporter belt was run, the waste stream Classified into iron, plastic, wood, glass and organic materials Based on the screening capacity of the machine. Where samples of equal size of cubic shape but different in specific density and according to the type of material were taken. Separation containers, but with different fall distances. Results Obtained from tests on the device shown in Tables 1–5.

It was noted from the results that there is a variation in the falling distances of the samples according to the type of material used, in addition to an increase in the falling distance as the conveyor belt speed increases, which gives an increase in the percentage of waste separation operations as shown in Fig. (7). The relationship between the density of the samples to be separated with the horizontal fall

*Table 1. Results obtained from the solid waste sorting machine test at speed 0.7 m/s.*

| Solid waste | Height (cm) | The distance (cm) | Speed of transporter belt (m/s) | Time taken to sort(Seconds) |
|---|---|---|---|---|
| sample of ferrous metallic materials | 40 | 14 | 0.7 | 0.27 |
| sample of Wood materials | 40 | 15 | 0.7 | 0.28 |
| sample of plastic materials | 40 | 15 | 0.7 | 0.26 |
| sample of glass materials | 40 | 13.3 | 0.7 | 0.31 |
| sample of Organic materials | 40 | 13.5 | 0.7 | 0.33 |

*Table 2. Results obtained from the solid waste sorting machine test at speed 1.11 m/s.*

| Solid waste | Height (cm) | The distance (cm) | Speed of transporter belt (m/s) | Time taken to sort(Seconds) |
|---|---|---|---|---|
| sample of ferrous metallic materials | 40 | 23 | 1.11 | 0.27 |
| sample of Wood materials | 40 | 24.5 | 1.11 | 0.29 |
| sample of plastic materials | 40 | 22.5 | 1.11 | 0.28 |
| sample of glass materials | 40 | 22 | 1.11 | 0.26 |
| sample of Organic materials | 40 | 24.5 | 1.11 | 0.29 |

*Table 3. Results obtained from the solid waste sorting machine test at speed 1.38 m/s.*

| Solid waste | Height (cm) | The distance (cm) | Speed of transporter belt (m/s) | Time taken to sort(Seconds) |
|---|---|---|---|---|
| sample of ferrous metallic materials | 40 | 29.5 | 1.38 | 0.36 |
| sample of Wood materials | 40 | 29.5 | 1.38 | 0.3 |
| sample of plastic materials | 40 | 30.3 | 1.38 | 0.29 |
| sample of glass materials | 40 | 30.2 | 1.38 | 0.3 |
| sample of Organic materials | 40 | 29.5 | 1.38 | 0.28 |

*Table 4. Results obtained from the solid waste sorting machine test at speed 1.66 m/s.*

| Solid waste | Height (cm) | The distance (cm) | Speed of transporter belt (m/s) | Time taken to sort(Seconds) |
|---|---|---|---|---|
| sample of ferrous metallic materials | 40 | 35 | 1.66 | 0.3 |
| sample of Wood materials | 40 | 33.5 | 1.66 | 0.28 |
| sample of plastic materials | 40 | 34.5 | 1.66 | 0.29 |
| sample of glass materials | 40 | 34 | 1.66 | 0.28 |
| sample of Organic materials | 40 | 35 | 1.66 | 0.28 |

*Table 5. Results obtained from the solid waste sorting machine test at speed 1.94 m/s.*

| Solid waste | Height (cm) | The distance (cm) | Speed of transporter belt (m/s) | Time taken to sort(Seconds) |
|---|---|---|---|---|
| sample of ferrous metallic materials | 40 | 41 | 1.94 | 0.29 |
| sample of Wood materials | 40 | 42 | 1.94 | 0.29 |
| sample of plastic materials | 40 | 42.5 | 1.94 | 0.29 |
| sample of glass materials | 40 | 42.5 | 1.94 | 0.29 |
| sample of Organic materials | 40 | 42 | 1.94 | 0.29 |

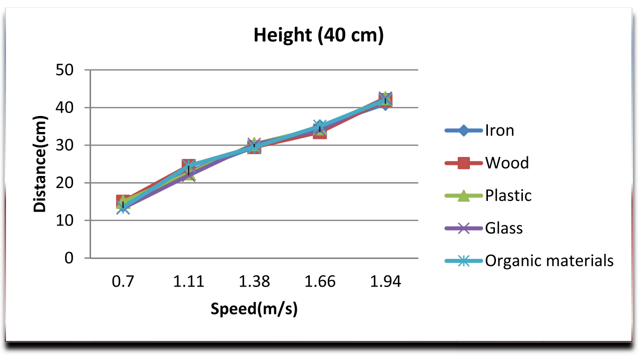


*Fig. 7. Variation in fall distance in variable speeds of multi materials.*

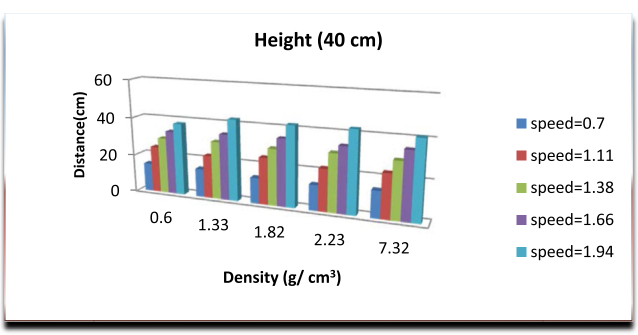


*Fig. 8. Shows the relationship between density and distance for a laboratory waste separator.*

distances of the samples during different parameters shown in Fig. (8).

## *5.2. Results of anaerobic Digestion Rig*

Local household waste was collected from sanitary landfill sites in the city of Baghdad, and the

*Table 6. Proximate analysis of materials used in model.*

| Material | Proximate analysis | |
|---|---|---|
| | weight of material (kg) | Percentage of material |
| Total weight of solid waste | 13.87 | 100% |
| Organic waste | 4.16 | 30% |
| Cow dung | 7.8 | 55% |
| Water (L) | 2 | 15% |

*Table 7. The result of Anaerobic Digestion Rig at average temperature weather (32.55 °C).*

| Time (day) | heat energy(J) |
|---|---|
| 1 | 0 |
| 2 | 0 |
| 3 | 0 |
| 4 | 0 |
| 5 | 0 |
| 6 | 0 |
| 7 | 836.8 |
| 8 | 1297.04 |
| 9 | 3932.96 |
| 10 | 5941.28 |
| 11 | 5104.48 |
| 12 | 5648.4 |
| 13 | 4351.36 |
| 14 | 5355.52 |
| 15 | 6066.8 |
| 16 | 5606.56 |
| 17 | 8535.36 |
| 18 | 7363.84 |
| 19 | 10,083.44 |
| 20 | 10,041.6 |
| 21 | 4518.72 |
| 22 | 10752.88 |
| 23 | 5648.4 |
| 24 | 3096.16 |
| 25 | 6443.36 |
| 26 | 6401.52 |
| 27 | 1631.76 |
| 28 | 1087.84 |
| 29 | 460.24 |
| 30 | 669.44 |

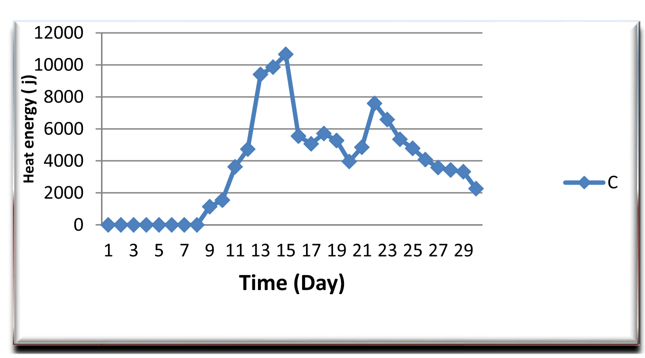


*Fig. 9. Shows the relationship between heat energy and the time for an Anaerobic Digestion Rig at average temperature weather (32.55 °C).*

waste was sorted manually and the various organic wastes were extracted with the isolation of inorganic waste, because anaerobic digestion processes depend in particular on organic matter. After fermentation of waste with certain percentages of waste with water with stimulating substances for bacterial decomposition (Cow dung) as shows in Table 6. The results shown in Table 7 were obtained for the amounts of energy produced by anaerobic Digestion. Fig. (9) shows the relationship between heat energy and the time at average temperature weather (32.55 °C).

## 6. Conclusion

Global population growth has an impact on the environment. One of the biggest environmental issues of our day is the rising amount of urban solid waste. On the other side, population expansion increases the need for energy. Waste disposal that is turned into energy will aid humanity in addressing these two important issues. Solid waste management has grown to be a significant concern in the majority of developing nations, including Iraq. In this study, a waste sorting machine that classifies municipal solid waste based on the material's specific density was created, together with a waste fermentation machine. This conclusion can be drawn from the performance evaluation results.

1. The waste falling on the conveyor belt acquires a linear speed and acceleration equal to the data of the conveyor belt, which leads to the extrusion of the material to a distance directly proportional to the belt speed.
2. The distance of samples falling into waste separation containers increases directly with the height of the waste separation device or the conveyor belt for throwing the waste.
3. The separation efficiency of samples increases when the speed and height of the conveyor belt used in the waste separation devices increase.
4. Through the equation that was found from the Takeuchi method, it is shown that the effect of the speed factor is greater than the effect of the height factor.

## Conflict of interest

None declared.

## References

[1] Naderi S, Banifateme M, Pourali O, Behbahaninia A, MacGill I, Pignatta G. Accurate capacity factor calculation of waste-to-energy power plants based on availability analysis and design/off-design performance. J Clean Prod 2020;275: 123167. https://doi.org/10.1016/j.jclepro.2020.123167.
[2] Rada E. Thermochemical waste treatment. Apple Academic Press.; 2017.
[3] Reddy P. Energy recovery from municipal solid waste by thermal conversion technologies. CRC Press; 2016.
[4] Khayamabshi E. Current status of waste management in Iran and business opportunities. Waste Manag. Occas. Smart Eng. Tokyo 2016.
[5] Faleh NM, Azzawi IDJ. Design of solid waste separation equipment in Baghdad city. J. Mech. Eng. Res. Dev. 2018; 41(3):1–5. https://doi.org/10.26480/jmerd.03.2018.01-05.
[6] Chulov M. Iraq littered with high levels of nuclear and dioxin contamination," study finds. 2010.
[7] Al-Muqdadi K. Beware of scrap iron from the remnants of war. Environ. Dev. 2006;8:16–21.
[8] Machrafi H. Green energy and technology. 2012.
[9] Nassif YR, Al-Anbari PDMA. GIS and Multi criteria Decision Analysis for landfill site selection in Karbala governorate. 2018. p. 2018.
[10] Hussein WA. Reuse of organic fraction municipal solid waste for production of electricity and composting materials by anaerobic digestion. 2014.
[11] Silwal Sristi CJ. Arentsen maarten, "waste to energy: solution for municipal solid waste management in kathmandu metropolitan city (kmc) master of environmental and energy managementvol. 74;31–2; 2019.
[12] Koech CC. Converting municipal solid waste to electricity for sustainable waste management: determinant factors for succKoech, C. C. 2015. p. 1–81. Converting municipal solid waste to electricity for sustainable waste management: determinant factors for successful set up.
[14] S. E. Anaerobic digestion of infectious biomedical waste with effective pretreatment techniques. 2010. p. 2010.
[15] Gebreslassie MG, Gebreyesus HB, Gebretsadik MT, Bahta ST, Birkie SE. Characterization of municipal solid waste's potential for power generation at mekelle city as a waste minimisation strategy. Int J Sustain Eng 2020;13(1): 68–75. https://doi.org/10.1080/19397038.2019.1645757.
[16] Osarue EO. Design and development of municipal solid waste sorting machine. Journals.Co.Za 2021;2(4):531–5 [Online]. Available: https://journals.co.za/doi/abs/10.10520/EJC156650.