A Comparative Study Between Municipal Solid Wastes Management Options in Processing Stage of Al-Diwaniyah city / Iraq

Mukhtar Dhajir Abbas¹, Ahmed Mahmoud Falih², Kareem G. M. AL- Mutawki³

¹Ministry of Environment, Environment Directorate of Al-Qadisiyah
²Ministry of Environment, Environment Directorate of Al-Qadisiyah
³College of Science, University of Al-Qadisiyah, Iraq
mukhtardhajir@gmail.com

Abstract

The plan of this study is determining the best option for solid waste treatment in the Diwaniyah city – Iraq. where the comparison between two common options in solid waste treatments, the first option is the incineration process with energy recovery for all waste components and the second option is "reusing inorganic and recycling organic compost" (RIROC). In this study, we depended numbers of criteria that included the environmental impact, the cost Investment, operation and maintenance costs, financial benefits, work experience, stabilization, quantities of by-product waste, and city needs. Due to the nature of wastes which contain high organic component and also high moisture content which decreases the low heating value of MSW where it is (6000 - 7000) KJ / Kg. According to these parameters and the wastes properties, the second option (RIROC) was the suitable choice due to the investment cost is less than the incineration option and the net profits are similar approximately where the net profits of the incineration and (RIROC) are $11888/day and $11597/day respectively.

Keywords: - compost, incineration, RIROC & solid wastes.

Introduction

The increasing of municipal solid waste MSW generation is the major issue and concern that face the countries and especially the developing. Disposing of the MSW on open dumps can causes many negative, economic and environmental impacts [1]. Therefore, the authorities should be find scientific and proper practice for MSW treatment and the solid waste should be regarded as-a resource in the incorrect place. [2].

The sound management of MSW must be in each stage of the operation such as generation, collection, transfer, transport and disposal. For a proper management in disposal stage, the compositions and quantities of MSW must be known for selection the suitable method and creation the environmental requirements, public health, preservation of resources, economy and other aesthetics [3].
A few methods of MSW treatment have been used in another nations are landfill, recycling, composting, gasification, pyrolysis, refuse derived fuel (RD) and incineration have less environmental impact than existing method [4,5].

The incineration of SW is classified according to its work into two manners with energy recovery and without energy recovery [6]. The incineration reduces the weight and volume of MSW by 70% and 90% respectively. [7]. incineration without recovery of energy is not a favored option due to financial costs and high pollution [6]. Therefore, the average low heating value of SW is 7,000kJ/kg which determined for operation of an incineration for energy generation. [8].

Before incineration installation, the energy content of MSW components must be known, there three models for energy content estimation are: the first model is "the Physical composition" which depends on MSW components percent such as (food, plastic, paper, textile and so forth), the second model is "the ultimate analysis" which depends on (chemical content of MSW such as carbon, nitrogen, hydrogen, oxygen and sulfate) and the third model is "the proximate analysis" which depends fixed carbon, volatile matter and water content. Depending on low heating value (LHV) that result from above models, the option of incineration installation must be active or not. [9].

The advantages of using incineration are less area need than landfill and possibility of power generation, the disadvantage are high costs, expert personal for running, not all MSW components are combustible, sometimes, additional fuel to sustain combustion or to start, air pollution by flue gas and soil contamination by ash residues. [10].

From the management and treatment methods of wastes disposal are "Reuse of Inorganic components and Recycling of Organic Components"(RIROC) where most of waste components can be reused and recycled such as a raw material for some industries or for energy generation. [4] and the organic components recycled for compost production. The compost is aerobic degradation for organic waste which the food waste is predominant in developing countries where the organic waste convert into humus and then to form organic fertilizer or conditioner for agricultural soil [11]. Recycling of organic wastes is significant for the cycle of carbon by which the environmental impacts of organic wastes is reduction [12].

The type of compost depends on the component of organic solid waste and also many factors that affect the compost process such moisture which must be (40-60%) [11], temperature which must be (25 to 40°C) for mesophilic phase and don’t exceeds 65°C for thermophilic phase [13], particle size, the Carbon: Nitrogen (C:N) ratio which must be (25-30:1), pH and oxygen concentration. [11,14].

The most three technologies of compost production are "open windrows" which is a narrow and long piles where the organic waste is placed with high ranged from (0.9 to 3.6) m and the width from (3 to 6) m, the determination of a wind-row size depends on porosity of MSW to be aerated successfully. The aeration achievement by turning mechanically to provide the necessary oxygen and take (4 to 6) weeks for process complete [2]. windrow method is the most appropriate way with low investment for organic waste recycling. [2,15].

The aerated static piles separately or in extended piles with high ranges from (2.5 to 4) meter, the air is supplied from down by mechanical instruments (blowers) without turning and the duration of compost production (3 to 5) weeks. The third technology is the in-vessel
composting is containers or vessels used to speed up the composting process by the control aeration, mixing, temperature therefore it is the costliest among the compost technologies [11]. Before using the compost for agricultural applying, it is significant to measure the heavy metals content to assess the toxicity [2].

There a lot of global studies are concerning management of solid wastes with different ideas as shown in the mentioned references. In Iraq, there many studies conducted mechanisms of solid wastes management in different cities where in Baghdad [16], in Basra [17] and in Erbil [18].

**Study area**
The study area is Al-Diwaniyah city placed in the middle of Iraq (about 180 km south of Baghdad) where the population is about (403,726) persons. The average temperature of it ranged from 35°C in summer to 10°C in winter but the standard is 23°C roughly and the total area is (818831) hectare and the agricultural area is more than 56% where is equal to (461175) hectare.

**Study objective**
The comparison between two options, the incineration process and (RIROC) option due to number of criteria that included the environmental impact, and the cost investment, operation and maintenance costs, financial benefits, work experience, stabilization, quantities of by-product waste, and city needs.

**The Methodology**
The study depends on two parts, practical and theoretical: -

1- **Practical:**
   - Sort the municipal solid wastes to identify the components percentages.
   - Account the generation rate of capital to identify the total quantity of SW.

2- **Theoretical:**
   - Financial comparison between the energy recovery by incineration method and compost production by aerobic degradation.
   - Environmental comparison between the incineration and compost.

**Materials and Methods**

**Generation Rate:** -

The generation rate of solid waste in AL-Diwaniyah city was measured directly from generation source by receipt the MSW from each house then weight it and in different interval, this step was worked for making sure the municipality directorate data where the results were ranged (0.8 – 1.1) kg/day. Capita.

**The Sort Practice:** -

The sort procedure was made in a transfer station where have been selected a sample represent residential wastes with 150 kg and then sorted all components manually by using balance and the results was as show in below table. The moisture percentage of food wastes was more than 70%. (Figure 1,2).
Figure 1 shows the average percentage of the components of SW in the city of Diwaniyah / Iraq.

Figure 2 shows the average Quantity of the components of SW in the city of Diwaniyah / Iraq.

Treatment Options:

There many methods for MSW management which represented with reusing, recycling and recovery, this study conducted the comparison between these two choices incineration with energy recovery and (RIROC) process according to (installation cost, operation and maintenance cost, labor experience, environmental impact, the city requiring, economic benefits and solid wastes quantity.

Incineration

Combustion process is two stages the drying and the burning of MSW. The final result of the incineration process is CO2, water vapor and residues with a high amount of heat. the required temperature is very high where ranging from (980 to 2000 °C). In India, the
incineration application is less using due to the nature of MSW composition i.e. high organic component (40% to 60%), high water content (40% to 60%) and available of inert material (30% to 50%) and the calorific value is low (800 to 1100 kcal/kg) where Calorific value must be between 1200 to 1400 kcal/kg for energy production. [19]. The average heating value that produce from MSW must be 6000 kJ/kg for all seasons of a year and the annual average not less than 7000 kJ/kg, but some studies determined that the lower heating value must not be less than 6500 KJ/Kg.[20]

### Economic

Incineration can be used to combust the MSW for recovery the energy with heat or electricity configuration, the magnitude of electricity that result from incineration by burning all combustible components such as PL(plastic), G(garbage), PR(paper), FO(foood), WO(wood), TEX (textile), Cd (cardbord) and Rb (rubber) with quantity reach to (320) ton/day was estimated (106.7) MW.h.

| Ref. | Model | LHV (KJ/Kg) | Electricity (MW.h) | * Profitability $/day |
|------|-------|--------------|-------------------|-----------------------|
| [5]  | LHV= 88.2PL+ 40.5 (G+PR) – 6W | 6950 | 123.6 | 43260 |
| [9]  | LHV=2229.91+7.90 PR +28.16 PL +4.87 G - 37.28W | 4872 | 86.6 | 30310 |
| [21] | LHV=[88.2 PL +40.5(FO+ PR)]* ((100-W)/W)-6W | 10171 | 180.8 | 63210 |
| [22] | LHV= 219PL+112PR+ 108WO + 115TEX | 3164 | 56.25 | 19688 |
| [19] | HHV = 53.5 (F + 3.6 (PR+Cd) + 372 (PL+Rb) | 5626 | 100.02 | 35007 |

* the average of investment price of electricity is 0.35$ /KW.h.

The energy that result from incineration depended on above lower heating values (LHV) can be calculated from below equations (1 and 2)

Electrical energy(KJ) = LHV * SW * f₁ *(100- f₂-f₃) .......................................... 1

Where SW (solid waste quantity (ton), f₁ (energy recovery efficiency of system 25%) , f₂ (heat loss 11%) , f₃ (station service allowance 9%).

Electrical energy (KWh) = LHV * SW * f₁ * (100- f₂-f₃) *(1/3600) ...................... 2.

The of incineration construction , maintenance and operation cost is summarized in table 3. The total costs mean the price of incineration completely and civil and mechanical of facility. The cost of MSW Collection from source to landfill and Incinerator land acquisitions have been neglected whereas these costs are required for any kind of MSW treatment.
Table 2: shows the total cost of incineration cost.

| Ref. | Country | SW Quantity ton/day | Investment Cost of incineration million $ | O & M cost $/ton | O & M cost $/day | Total cost $/day |
|------|---------|---------------------|------------------------------------------|-----------------|-----------------|-----------------|
| 6    | * U.S.A | 320 (for this study) | 350---360                                 | ------          | 235000          | 66400           |
| 23   | **Brazil| 55 --- 1600         | 62.2                                      | 23.2            | 7424           | 14240           |
| 24   | China   | 210                 | 101.8                                     | O= 15.3         | 11370          | 22526           |
| 25   | Uruguay | 2300                | 420                                       | ------          | 60274          | 106301          |
| 26   | UK      | 400 ---1000         | 160 --- 220                               | 70              | 22500          | 43322           |
| 4    | ***Iran | 320                 | 23.75                                     | ------          | 7000           | 9602            |
| 27   | India   | 1300                | 18.2                                      | ------          | 2935           | 4930            |
| 28   | Colombia| 320                 | 20.862                                    | 4% * invest. Cost | 1715           | 4001            |

* The cost values were calculated from the charts due to the SW quantity of case study.
** Y=5000X^{0.8} , Z=700X^{-0.3}
X is the plant capacity in tones/year, Y is the initial capital investment (€), Z is the O&M (€/tones)
(for facilities with capacity range of 20 ≤ X ≤ 600 (10^3 tones year -1).
*** Total Cost = 70000*(ton/day), M&O Cost = 7% *Total Cost.
Note:- assume the life span is 25 years for total cost calculations.

Environmental Impact
The polluted gases that result from incineration plant during waste combustion such as carbon monoxide, carbon dioxide, sulfur dioxide and nitrogen dioxide, the burning of plastic produced high quantity of carbon dioxide and also release toxic chemical components called "Dioxins" which are by-products in combustion plants like incineration, and are an indirect outcome of partial combustion. Dioxins cause health problem such as skin disease, liver, heart, kidney, diabetes, blood disorders and cancer[10].

The nitrogen dioxide (NO2) is a significant factor for nutrient enrichment and acidification. About 74% of the nutrient enrichment and acidification potential are produced from nitrogen dioxide.

Table 3: shows the environmental impact of incineration

| Potential Impact                  | Emissions |
|-----------------------------------|-----------|
|                                   | CO2 | CO | NOx | SO2 | HCl | Dioxins |
| Global warming.                   | ✓   | ✓  |     |     |     |         |
| Acidification                     |     | ✓  | ✓   | ✓   |     |         |
| Nutrient enrichment               |     |    | ✓   |     |     |         |
| Human and animal toxicity         | ✓   | ✓  | ✓   | ✓   |     |         |
The compost and inorganic component reusing

Economic Aspect

Table 4: shows the compost and reusing income.

| Components | Reusing | Compost |
|------------|---------|---------|
| Plastic    | 9.8     | 16.5    |
| Paper      | 5.7     | 5.7     |
| Glass      | 3.92    | 1.6     |
| Metal      | 12.5    | 9.1     |
| Food       | 16.5    | 5.7     |
| Wood       | 12.5    | 5.1     |

| Dry weight % | 9.8 |
| Quantities (tons) | 31.4 |
| Payment ($/ton) [18] | 125 |
| Profitability $/day | 3925 |

Total ($/day): 7637

Table 5: shows the construction cost of compost and sorting plant.

| Compost plant | Sorting plant |
|---------------|---------------|
| Investment cost (million $) | O & M Cost ($/year) | Investment cost (million $) | O & M Cost ($/year) | Total cost $/day |
| 1.2*          | 145,000       | 5*              | 500,000 (10% invest. cost) | 2740           |

*- The cost depend on the available prices in the international markets and experts estimations with the life span is 25 year

The Result And Discussion: -

Economic aspect: -

The investment cost of incineration is (100,000) $/ton. day [4] according to Korea offers with operation and maintenance is 25% of investment cost yearly and the reasons of this choice of cost is due to the economic similarity with Iraq. The average of low heating value of MSW was estimated (6000 to 7000) KJ/Kg and because the economical purpose, the minimum value was depended (6000) KJ/Kg. The average total cost and profits of a incineration is close into the RIROC method but the investment cost of incineration is expensive.
Table 6: shows the comparison costs and profits.

| Financial value | First Option | Second Option |
|-----------------|--------------|---------------|
|                 | Incineration | Recycling (Compost) & Reusing |
| Total Cost $/day | 25430        | 2740          |
| Profits $/day   | 37318        | 14337         |
| Average cost    | 11888        | 11597         |
| Net profits $/day | -            | -             |

* the life span is 25 year

The others comparison parameters is shown the below table which RIROC method is more suitable due to the environment and human health.

Table 7: shows the comparison parameters between incineration and RIROC method .

| Parameters               | Incineration with energy recovery | RIROC method |
|--------------------------|----------------------------------|--------------|
|                          | Compost production from organic materials | Reusing of inorganic components |
| Environmental impact     | High                             | Low          |
| Air pollution            | High                             | Low          |
| Water pollution          | Low                              | High         |
| Soil contamination       | High                             | High         |
| Financial benefits       | High                             | High         |
| Capital cost             | High                             | Low          |
| Experience               | High                             | Low          |
| Residues hazardous       | High                             | Low          |
| Break off potential      | High                             | Low          |
| Market demand            | High                             | High         |

Hence, the reusing and recycling is more suitable than incineration process with energy recovery of wastes in the city of Diwaniyah / Iraq according to:

- Less environmental impact.
- Less total cost, less experience requirements.
- High organic components and high moisture content in waste is significant factor in compost production.
- Agricultural nature of the city is encouraging factor of compost production.
- Because the little quantity of waste generation, the incineration (recovery) option is no high benefit financial.
- The electricity in Iraq is pricy therefore the profits of incineration is close into the RIROC method profits.
Recommendation

- Work study to the large cities where the waste quantity more 1000 ton per day.
- Study other options such as gasification, paralysis and so on.
- Specialist study on nature of produced compost.

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