Mohammad Fawzi al Ajlouni¹, Mohammed KHATTAB²

Assistant Professor, Head of Civil ¹
Engineering Department at Jerash
. Universit

Ph.D. Student, LARGHYDE laboratory, ²
Department of Civil Engineering,
. University Mohamed Khider, Biskra

¹ e-mails: m.ajlouni@jpu.edu.jo
² e-mail: mohammed.khattab@univ-
biskra.dz.

Keywords
Al-Akaider landfill
organic waste
solid wastes
biogas, compost.

Abstract
Jordan has been facing a wide variety of sudden changes in humanitarian issues (population growth, industrialization rapid, urbanization process, influx of refugees to Jordan etc.). These unexpected changes forced people to make quick reactions to adapt and settle which resulted in further generation of solid waste which normally was dumped in landfills and caused contamination of soil, water and air. Solid Waste Management (SWM) has been an integral part of every human society. Improper SWM accelerates natural resources degradation and has a great impact on climate change and the quality of life of citizens. Hence, in this paper, we highlight the environmental and health problems of the Al-Akaider landfill in Jordan. We propose a multi-pronged integrated approach to improve solid waste management at the Al Ekaider landfill. In keeping with this approach, a general action plan has been proposed that could be tailored to recycle Organic Waste (OW) to produce biogas and compost.

© 2018 JASET, International Scholars and Researchers Association
1. Introduction

Solid waste is defined as any material that is not useful and does not represent any economic value to its owner (waste generator). Population growth, rapid urbanization, booming industrialization and construction of infrastructure and house building activities create huge amounts of the solid waste. The solid waste includes materials such as wood, glass, plastic, bricks, gypsum, metals [1-2], construction and demolition waste [3-6] and agricultural waste, household food waste, human wastes [7]. Solid waste is usually disposed of in places called landfills. Meanwhile, this waste becomes degradable and will be broken down into simple organic molecules, carbon dioxide, water or methane by the action of microorganisms, which poses a great threat to the environmental, including ecosystem destruction, and harm to human health. For example, Al-Akaider landfill is one of the hot environmental spots in northern Jordan, located within the yarmouk basin (Fig. 1). Solid waste deposition in the landfill started in 1981. Some studies have investigated the environmental and health risks associated with the Al-Akaider landfill. In a study carried out by Renew, (2006) and aims to assess the risks of industrial wastewater ponds and leachates in the Al-Akaider landfill on groundwater and the risk assessment of gaseous emissions released from the landfill in the surrounding environment. Based on the result, he found that contamination of groundwater by leachate has already occurred. The author also found that the carcinogenic and non-carcinogenic risks for the residents of Al-Akaider village (1,580 m southwest of the landfill) were minimal, while not acceptable for the workers. In addition, the results illustrated that the vegetation will be affected by oxygen depletion and the presence of carbon dioxide and methane in concentrations higher than 7.5% (by volume) in the root zone at a distance of 157 m around the landfill [8]. In another research, BanyYaseen et al (2018) researched the potential pollution of the groundwater around Al-Akaider landfill waste area. According to their result, they found that the concentrations of Zn, Cu, Mn, Pb, Cd and Fe in all the tested water samples have been within the maximum permissible limits of Jordanian drinking water [9].
This research addresses the important environmental problem of how to improve SWM and biodegradable waste in particular at the Al-Akaider landfill. Although some studies discussed below have been performed on recycle solid waste to produce biogas and compost around the world. As a matter of fact, no studies about how to recycle solid waste in Al-Akaider landfill to produce compost and biogas. So, this experimental program intends to fill this gap, contributing to the possibility of using solid waste in Al-Akaider landfill for the production of biogas and compost

Literature review

The literature review showed that there is a lack of information regarding the recycling of the solid waste in the Agadir landfill from an environmental and economic point of view, especially for the production of biogas and compost. The general features of a few selected experimental researches concerning the recycling of the solid waste analyzed in the present article are briefly described next.

Woon and Lo, (2015) researched the conversion of food waste to biogas as a renewable energy source. According to their result, they found that the use of food waste
as biogas fuel for vehicle use in Hong Kong is an effective approach [10]. Woon and Lo, (2015) [10] stated that, there are a few companies practicing the conversion of food waste into different valuable materials in Hong Kong such as compost, swine feed and fish feed. The government of India has taken a significant step in waste management under the municipal SWM rules (2016). In this context, waste to wealth policies was made where the organic waste either be used in composting or anaerobic digestion to generate energy Pujaraa et al. (2019) [11].

Taiwan's environmental protection administration has enacted a food waste recycling policy since 2003 as an alternative to landfills and incineration for municipal solid waste disposal Chen (2016) [12].

Salomon and Lora, (2009) led to the conclusion that the production of biogas out of the organic residues coming out from the sugar and alcohol industry (vinasse), urban solid and liquid wastes (garbage and sewage) and livestock residues (bovine and swine manure) in Brazil of electricity production could meet the energy demand of about 1.05 to 1.13 % [13]. In Thailand, the compositions of waste (86%) are mainly OW, paper, plastic, glass, and metal. As a result, Thailand’s national waste management policy has started to encourage local administrations to set up central municipal solid waste disposal facilities with appropriate technologies and reduce disposal costs based on the amount of local solid waste generated Kaosol, (2009) [14].

DEMIRBAS, (2006), stated that biogas can be obtained from digesting the organic material of municipal solid wastes to fuel urban heat space in Turkey [15]. In other work, Anjum et al. (2016) reported that the anaerobic digestion can be used to treat the organic part of municipal solid waste. Therefore, the methane produced during the process can be used as fuel [16]. On the other hand, Balla et al. (2016) reported that energy generated from biodegradable municipal solid waste is the most appropriate process to reduce greenhouse gas emissions [17]. In Malaysia, some of the important policies have been implementing on renewable energy towards effective implementation of biogas generation from municipal solid waste Bong et al. (2017) [18]. Krishnan et al (2018) Research into the possibility of extracting carbon from fly ash which is the product of the combustion of waste particles. It was found that carbon extraction in semi-liquid form can be extracted after the waste is incinerated in the chamber and condensed by the condenser. Further, the authors also found that the hot steam and steam generated during the combustion process can be used in the rotation of the turbine [19].

Analysing the results reported by these authors, one can conclude that solid waste can be used for the recovery of valuable materials. therefore, solid waste is one solution that must be financially sustainable, technically feasible, socially, legally acceptable and environmentally friendly. In fact, Abdel-Shafy and Mansour (2018) [20] reported valorization of solid wastes is one of the important current research areas.

**Problem statement**

The generation of solid wastes in general and biodegradable waste in particular is increasing at the Jordan level over the last two decades. Solid waste mismanagement in Jordan, illustrates a well-known market failure which can be summarized as:
(a) Jordan currently produces approximately 2.7 million tons of waste every year, and it is estimated that this will increase to over 6 million tons annually by 2040 [21].

(b) Lack of coordination among the various governmental entities responsible for different aspects of SWM.

(c) Landfills across Jordan have been identified as having a high risk of contamination due to uncontrolled disposal, treatment and operational management.

Research Objectives

Jordan is characterized as a resource-scarce country. With limited primary energy sources, the country imports a large amount of these resources to meet the needs of its population.

The main objectives of this paper are to demonstrate the potential of converting biodegradable waste at Al-Akaider landfill into renewable energy in the form of biogas for use in the energy sector, currently largely dependent on fossil fuels.

Furthermore, the potential for converting and using OW as a fertilizer in the nutrient-hungry agricultural sector that currently relies heavily on chemical fertilizers.

Methodology

Al-Akaider landfill receives solid waste with an amount of 800 tons/year generated from the residents of about 62 villages and cities in northern Jordan. Taher et al., (2021). This solid waste is composed of materials such as paper, cardboard, metals, glass and plastics. The composition of solid waste generated by the Jordan in 2014 is given in Fig. 2. It can be observed from Fig. 2 that the OW occupies the largest proportion of solid waste (about 50%). In this regard, approximately of 400,000 tons of OW are disposed of in Al-Akaider landfills every year. OW waste refers to the solid waste containing organic components, including (e.g., crop straw, livestock manure, green waste, food waste).

Fig. 2. Composition of solid wastes generated by the Jordan in 2014 [22].

Generally, solid wastes have variable physical and chemical characteristics depending on their original sources, therefore, we can say that solid waste is heterogeneous in nature. The heterogeneity of solid waste is the main obstacle to sorting and its use as a material. In Jordan, the generated solid waste, particularly the OW, is not separated from other types of solid wastes prior to discarding in the landfills. In other word, solid waste fractionation and sorting are a critical step in dealing with the increasing problem of waste before any meaningful treatment process. As such, a high behavioural change of the population is needed for the collection and separation of solid waste. Woon and Lo, (2015) [10] in their study concluded that solid wastes can be efficiently separated via an optic bag system. For example, a green bag can be used to pack the food waste (contain organic material), while the remaining solid wastes can be packed in a common plastic bag. The optic bag can be classified into two groups.
depending on size: the first groups have a size of 10 L [width = 270 mm, depth = 130 mm, height = 30 mm], and the second groups have a size of 30L [width = 300 mm, depth = 220 mm, height = 640 mm] Mepex, (2014) [23]. In Linköping, Sweden, about 80% of local families in this city adopt the optical bag system Book, (2014) [24]. By doing so, the population will not be required to change to a new place for the sorting of solid waste. Then, all the bag waste will be collected by the garbage truck and transported to the respective waste stations in Jordan. Upon arrival at the refuse transfer stations, all the bag waste will be emptied into a reception pit to sort the bags. Then, all the bags will be sent to a main conveyor belt, where optical sensing technology will be used to sort the bags. When a green optical bag (contain food waste) is detected, a signal will be sent to push the green bag from the main conveyor belt to the second belt. An automatic bag-opener system can be used to separate the collected food waste from the optical bag. Finally, the food waste will be broken into small pieces and will be compressed and placed in containers, and then transported to various food waste recycling facilities for further processing. Meanwhile, other remaining solid waste such as plastic and paper, packed in common plastic bags, will be sent to specialized recycling facilities. Fig. 3 illustrates a simplified diagram for separating the optic bag of green color from other bags in an optical sorting plant operated by the Tekniska verken company. According to Woon and Lo, (2015) (as cited in Envac, 2014) in Oslo, Norway, the Haraldrud sorting plant handles optic bag sensor technology since 2009 for separating food waste from other solid waste.

In the Al-Akaider landfill, the situation is completely different, as the landfill contains thousands of tons of solid waste of different nature. Therefore, the waste sorting process requires great effort. To fractionate and sorting of these wastes, the Jordanian government should work hand-in-hand with the local industry, consumers and local communities.

**Fig. 3. Simplified diagram of process optical sorting for solid waste in Linköping city, Sweden Woon and Lo, (2015)[10].**

**Results and discussions**

**Valorization of organic waste to biogas products in Al-Akaider landfill**

As mentioned above, about 50% of waste generated in Jordan is classified as OW. In 2012, approximately 34.5% of food wastes were generated and is disposed of in landfills [22]. Dumping technology can be widely applied to OW, but it also has obvious negative environmental impacts. For example, leachate production and greenhouse gas emissions (such as methane...
and carbon dioxide) are the most important limiting factors for the dumping of organic solid waste. Traditionally, the most widely used model is shifting to waste-energy approaches, which has been successfully applied to treat and valorize food organic waste.

Biogas can be obtained from various sources. Decomposing food organic waste is among of these sources. Biogas is being used in the agricultural and industrial sectors and household use such as cooking, heating and lighting KARNATAKA, (2005) [25]. Table 1 shows the typical composition of biogas. It can be observed from table 1 that the methane is the most important component among the composition of biogas.

<table>
<thead>
<tr>
<th>Component</th>
<th>Methane</th>
<th>Carbon Dioxide</th>
<th>Hydrogen Sulphide</th>
<th>Nitrogen</th>
<th>Hydrogen</th>
<th>Carbon Monoxide</th>
<th>Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical formula</td>
<td>CH4</td>
<td>CO2</td>
<td>H2S</td>
<td>N2</td>
<td>H2</td>
<td>CO</td>
<td>O2</td>
</tr>
<tr>
<td>Content (%)</td>
<td>55 – 65</td>
<td>35-45</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
<td>0-3</td>
<td>0-2</td>
</tr>
</tbody>
</table>

The landfill gas is generally composed of Methane (40–60% by vol), Carbon Dioxide (20–40% vol.), Nitrogen (2–20% vol.) DEMIRBAS, (2006). As mentioned earlier, Jordan is characterized as a limited natural resources. In 2015, 97% of energy resources was imported Belda Gonzalez (2018) [27]. Therefore, the potential use of biogas from landfills leads to economic and environmental sustainability.

According to Bilhat, (2009) [28] Biogas is formed in four major processes namely (a) hydrolysis, (b) fermentation/acidogenesis, (c) acetogenesis, (d) methanogenesis. (see Fig .4). In hydrolysis, complex organic matter is decomposed into simple soluble organic molecules by using water to break down the chemical bonds between substances. The next process, fermentation, is the chemical decomposition of carbohydrates by enzymes, bacteria, yeast or molds in the absence of oxygen to form volatile fatty acids and some acetic acid, H2 and CO2. In the third process, the fermentation products are converted into acetate, hydrogen and carbon dioxide by the so-called acetate bacteria and in the final process, methane is formed from acetate and hydrogen/carbon dioxide by methanogenic bacteria.
Fig. 4. Stages in biogas production [28]

The biogas-to-energy roadmap has been divided into three stages, namely, municipal solid waste feedstock, biogas production, and biogas utilization Bonga et al. (2016) [29].

For municipal solid waste feedstock, there is several stages such as: waste segregation and collection.

Waste segregation and collection: input feedstock separation is a critical step in biogas yield. The input to anaerobic digestion should only consider OW, which can be decomposed by microbes and produced biogas under anaerobic condition. Solid wastes such as glass, plastics and will hinder the anaerobic digestion process.

Another major issue is dealing with the proper distribution of waste. OW can be used as raw materials for many waste-to-energy technologies, such as composting, anaerobic digestion and incineration. There will be competition between these technologies to get a large amount of waste to feed into their systems continuously for a long time.

Mapping initiatives with current policies and needed policies for stages 1: municipal solid waste feedstock. (1) Waste segregation and collection

As above mentioned, in Jordan, the generated solid waste, particularly the OW, is not separated from other types of solid wastes prior to discarding in the landfills. In light of this need, the Jordanian government should officially enforce mandatory household waste segregation for recycling purposes by introducing the optic bag system. The Jordanian government must currently prepare a national strategic plan for food waste management. The plan includes key strategies for managing food waste, which is (a) Reducing food waste at the source (b) Establishing a “Food Waste Recycling Regulation” (c) An appropriate central system for treating waste (d) Effective recovery of methane from landfill sites. Furthermore, the Jordanian government must currently prepare a strategic plan for fractionate and sorting of OW in the Al-Akaider landfill in order to harvested methane gas produced during the anaerobic decomposing of organic waste.

For biogas production, there are two main challenges for this stage: technological maturity Ahmad and Tahar, (2014) [30] and financial viability Bonga et al. (2016) [29].

Technological maturity: Technological maturity includes lack of experience and unfamiliarity with anaerobic digestion, its design and operation, and upgrading of biogas into a value-added product. Moreover, anaerobic digestion system involved several stages of biotransformation such as hydrolysis, acidogenesis, acetogenesis and methanogenesis. Each of these steps has its own operational requirements, particularly for methanogenesis. In order to improve the economic exploitation of methane, knowledge of the operational procedures of
anaerobic digestion will be required. Fig 5 indicates that the economic exploitation of methane is beneficial after one year from the start treating waste DEMIRBAS, (2006) [15].

financial viability: The construction, maintenance and operation of an anaerobic digestion laboratory can be significantly high. Thus, this does not attract potential investors due to the high financial risks. In order to attract investors, the government should provide more tax exemption on anaerobic digestion technology due to its high capital and operational cost.

![Production of biogas components with time](image)

**Fig 5. Production of biogas components with time [15].**

Mapping initiatives with current policies and needed policies for stages 2: Biogas production

The current policies in Jordan do not have any of the actions that support capital development and research development to maximise the biogas yield. For example, the operation and maintenance of an anaerobic digestion plant will require skilled engineers and technicians, which may be lacking in Jordan where anaerobic digestion is still not a common practice. In order to maximise biogas production and upgrading from Al-Akaider landfill, there would be a need to improve technical knowledge in anaerobic digestion and support procedures such as training and workshops on operational knowledge of anaerobic digestion. Furthermore, the Jordanian government should provide more financial support for processing units for pre-treatment and anaerobic digestion.

More efforts should be made to facilitate cooperation between government agencies and private institutions to construct an anaerobic digestion plant and to provide technical support to operators or investors with little experience.

Finally, the biogas utilization is the decisive factor in the economic feasibility of implementing an anaerobic digestion plant. It
has been proposed to use the biogas generated after anaerobic digestion as electricity LegCo, (2014) [31]. In addition, the use of biogas fuels produced from OW has been widely adopted in some European cities such as Linköping and Stockholm in Sweden, Lille in France and Oslo in Norway Woon and Lo, (2015) [10]. By using biogas fuel from OW, it reduces the use of imported fossil fuel supplies, as well as significantly reducing emissions of greenhouse gases, nitrogen oxides compared to gasoline and diesel fuels. Papacz, (2011) reported that biogas-fuelled vehicles can reduce greenhouse gas emissions by between 75% and 200% compared with fossil fuels [32]. Biogas fueled cars are currently manufactured by several major auto manufacturers such as Mercedes-Benz, Volkswagen, Ford and Volvo Woon and Lo, (2015) [10].

In view of economic perspective, the Jordanian government could adopt similar approaches to the use of biogas fuels. Besides, the Jordanian government can encourage the use of biogas-fueled cars. There must also be adequate infrastructure to generate electricity from biogas and route it to grid lines. For instance, a Linköping Biogas plant in Sweden has an annual processing capacity of 100,000 tons of organic waste and produces 4.7 million m³ biogas IEA, 2005 [33]. As noted in section methodology, approximately 400,000 tons of OW are disposed of in Al-Akaider landfills every year. Considering the 400,000 tons OW treated, it is estimated that about 18.8 million m³ will be produced annually. Assuming the private the price for selling 1 m³ of biogas is 38.5 USD cents (according to the state owned enterprise Perusahaan Listrik Negara (PLN)), which is an Indonesian government-owned corporation, Adam, (2017) [34]). Therefore, the biogas generates revenue from the sale of a total of 7.2 million US$.

Valorization of organic waste to compost in Al-Akaider landfill

As mentioned in the literature review section, the recycling of OW for compost production is an efficient technology and can reduce problems arising from waste disposal sites. Composting is one of the most widely used treatment method in Indian Pujaraa et al. (2019) [11]. In order to obtain compost material from OW, microorganisms such as bacteria, fungi, algae and protozoa degrade the organics under controlled environmental conditions Bohacz, (2018) [35].

Pujaraa et al. (2019) [11] concluded that there are four main reaction stages occurs in the composting process:

Mesophilic : Compost bacteria combine with oxygen to produce CO2 and energy. Temperature ranges from 30 °C to 40 °C.

Thermophilic : Thermophilic microorganisms digest the organic matter. Temperature may rise up to 70 °C.

Cooling Phase : Microorganisms which were replaced by thermophile migrate back to compost.

Organic matter digestion takes place : Maturation/Curing Temperature gradually decreases. Compost gets ready in few weeks to months.

However, the biggest challenge with this method is the survival of microorganisms in ideal ecological conditions, and therefore low-quality compost has a negative effect on soil properties and plant growth Anjum et al. (2016) [16]. Apart from the conventional methods for preparing the compost, some
advanced techniques of composting have been developed such as Bangalore method, Indore method and Coimbatore method Misra et al. (2003) [36].

Bangalore method: Organic residues and night soil are placed in alternate layers. After filling, the pit is covered with a layer of residues of 15-20 cm. The material is allowed to remain in the pit without water for three months. Additional night soil and waste are placed on top of it in alternate layers and covered with clay or earth to prevent moisture loss and fly breeding. It takes about six to eight months to get the final product.

Indore method: Compost can be prepared in piles above ground and protected with a shed. The pile is about 2 m wide at the base, 1.5 m high and 2 m long. The sides narrow so that the top is about 0.5 m narrower than the base. Pile formation usually begins with a 20 cm layer of carbonated material such as leaves, hay, straw, sawdust, wood chips, and shredded corn stalks. They are covered with 10 cm of nitrogenous material such as fresh grass, weeds, garden plant residues, fresh or dry manure or digested sewage sludge. The pattern of 20 cm of carbon and 10 cm of nitrogenous material is repeated until the pile height is 1.5 m and the material is naturally wet. The pile is sometimes covered with soil or hay to retain heat and turned over at 6- to 12-week intervals.

Coimbatore method: This method involves digging a pit (360 cm long x 180 cm wide x 90 cm deep) in a shaded area (length can vary according to the volume of waste available). Farm waste such as straw, vegetable waste, weeds and leaves are scattered 15-20 cm thick. Wet animal dung is spread over this layer with a thickness of 5 cm. Sprinkle water to moisten the material (50-60 % by mass). This procedure is repeated until the total mass reaches a height of 60 cm above the ground. Then it is coated with clay, and anaerobic decomposition begins. Within four weeks, the clay plaster is removed and the entire mass is stirred. Aerobic decomposition begins at this point. Water is sprayed to keep the material moist. The compost is ready for use after four months.

In Asian countries such as South Korea, Taiwan and Japan, more than 40% of the OW is processed into compost to partly substitute for chemical fertilizers Woon and Lo, (2015) [10]. There are many applications for composting materials such as preventing soil erosion, reclamation of land and soil and providing maximum nutrients for plants. In order to assess the quality of compost, many private and official authorities have established standards and regulations to check the quality of compost for agricultural applications and environmental protection. According to GCST,2006 (as a cited Anjum et al. (2016) [16] some arab gulf countries have also documented regulations on the quality of imported and local organic compost.

OW is an important source of valuable products like compost. There are huge and indisputable profits associated with organic waste for countries like Jordan. As current practices in the Hashemite Kingdom of Jordan are not very efficient for compost recovery from OW. Richard, (2016) stated that the compost generated from 1 tons of organic waste equals to about 0.25-0.5 ton [37]. Considering the 400,000 tons OW treated, it is estimated that about 100,000-200,000 tons will be produced annually. Assuming the private the price for selling 1 tons of compost is 38.5 USD cents (according to the ???). Therefore, the compost generates revenue from the sale of a total of
Conclusion

As a conclusion, this paper presented several key policies in the development of waste management in the Al-Akaider landfill and the recycling of OW for the production of biogas and compost. Some studies have given evidence that contamination of soil, water and air has already occurred around the Al-Akaider landfill waste area. The benefits and ways of fractionation and sorting of solid waste in Jordan are explained in this paper. Furthermore, the optic bags system is proposed for separating organic wastes from other types of solid wastes, and thus to encourage the Jordan public to implement food waste separation at the source. This paper also discusses the possibility of conversion of OW in the Al-Akaider landfill to biogas as a renewable energy source in Jordan. Meanwhile, composting is an effective technology for recycling organic waste into valuable products and can reduce problems arising from landfill. Composting can reduce 20-25% of carbon emissions from organic and help reduce landfill disposal Pujaraa et al. (2019). Finally, the waste recycling and material recovery sector presents an economic opportunity to sustain landfill infrastructure, improve the livelihoods of many Jordanians, and provide green jobs and teach new skills to the public.

Recommendations

The Jordanian government and public should work hand-in-hand to alleviate the existing bad condition of landfill disposal, in particular the Al-Akaider landfill.

The Jordanian government should allocate sufficient financial, human and technical resources to separate and sort solid waste before reaching a waste landfill.

Key line ministries, including the ministry of the environment, should support research to produce the biogas from organic wastes.

The Ministry of agriculture can adopt the use of compost from organic wastes. Therefore, compost is an economical and eco-friendly approach for waste management.

Acronyms list:

SWM: Solid Waste Management

OW: Organic Waste

Conflict of Interest

No potential conflict of interest was reported by the authors.

References


Khattab, M., Hachemi, S., & Al Ajlouni, M. F. Recycled Refractory Brick as Aggregate for Eco-friendly Concrete Production. Journal
Advanced Sciences and Engineering Technologies 04(2021)32-49.


Bong, Cassendra Phun Chien, Wai Shin Ho, Haslenda Hashim, Jeng Shiuon Lim, Chin Siong Ho, William Soo Peng Tan, and Chew Tin Lee. "Review on the renewable energy and solid


Al Naami, Adam. Techno-economic Feasibility Study of a Biogas Plant for Treating Food Waste Collected from Households in Kartamantul Region,


Richard, Tom L. "Municipal Solid Waste Composting: Physical Processing, Fact Sheet 1 of 7, Department of Agriculture and Biological Engineering, Cornell University." (2000).