Characteristics of Selected Waste-To-Energy Technologies and Suitability for Oman

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The fast economic development and urbanization caused rapid increase of waste generation worldwide. Oman produced 1.5 million tons of municipal solid waste (MSW) in 2012 which is expected to elevate to 1.89 million tons in 2030. This rapid increase needs to be tackled to reduce the generation rates along with the environmental impacts it imposes. Currently in Oman other than recycling there are no treatment facilities, and therefore dumping waste into the landfill is the only and ultimate way to dispose solid waste. Thus this research aims present the process and specific aspects of Waste-To-Energy (WTE) technologies and determine the suitable technology for Oman depending on its waste composition and characteristics. In conclusion, the waste characteristics shows the potential to set up a WTE technology in Oman which will help to reduce the amount of waste, greenhouse gas emissions, developing and maintaining costs of landfills, and tackle the issue of portable water by using the produced energy for seawater desalination.

**Keywords:** biochemical; technologies; feedstock; thermal technologies; waste-to-energy; waste management

**Introduction**

The generation of waste has rapidly increased worldwide owing to the fast-economic development and urbanization. In GCC, Oman has made the most rapid progress in the development within a short period of time (M. Samah, 2011). Oman produced 1.5 million tons of municipal solid waste (MSW) in 2012 which is expected to elevate to 1.89 million tons in 2030 Be‘ah (2016). This rapid increase in waste generation rates is a challenging issue for the Sultan of Oman because of the limited land availability, and increased greenhouse gas emissions owing to the disposal of majority of MSW to 350 authorized and unauthorized dumpsites (Zafar, 2016). Oman’s current waste management system is struggling to handle the growing amounts of waste and this issue is difficult to be resolved if Oman purely focuses on waste disposal. Therefore the current situation urgently requires to improve waste prevention, set up MSW energy recovery plants for the reduction of mass and volume of waste, and to alleviate health hazards from pollution. In Europe for thermal and electricity generation around 40 million tons of MSW is incinerated yearly, whereas worldwide 130 million tons of MSW is combusted annually (J. Nixon, 2010). Oman’s primary energy consumption mix consist of 30% and average energy content of 10MJ/kg (Al-Harrasi, H., Personal Communication, Dec 7, 2016). Oman’s current waste energy contribution and heavy reliance on fossil fuels could lead to the loss of natural resources in future (I.Velghe, 2011).

The composition of MSW in Oman involves 27% food waste, followed by 21% plastic, 10% carton, 6% glass, 6% textile, 5% park and bio waste, 5% paper, 2% wood with the moisture content of 30% and average energy content of 10MJ/kg (Al-Harrasi, H., Personal Communication, Dec 7, 2016). Be‘ah (2016). The average energy content of waste in Oman shows the potential of energy recovery. There are many established and emerging thermal Waste-to-Energy (WTE) technologies. The thermal WTE technologies include incineration, gasification, pyrolysis and hydrothermal carbonization (HTC) C. He, A. Giannis, and J.Y. Wang, (2013), C. Tatarniuk (2007), C. Ducharme (2010). Each WTE technology process specific quality (composition and characteristics) and quantity of waste. Thus, for proposing a suitable waste management plan or technology for a particular place requires to consider its waste composition, characteristics and generation rates (A.S.Khan, 2011), C. Tatarniuk (2007), (M. Ouaïdi, 2013).

**Waste to Energy Technologies**

**A. Incineration Technology**


Reaction Type: Exothermic (R. Atwadkar, 2014).

Typical Waste Treating Capacity: 50,000 – 750,000 tons/year


Feedstock Requirements: Biological and Synthetic origin dry wastes (R. Atwadkar, 2014).

Preprocessing Method of Feedstock: Drying and Pelletization (R. Atwadkar, 2014), [27].


Efficiency (%): 50 – 60 % (R. Atwadkar, 2014).


Gasification is a thermochemical way of transferring organic material (biomass or MSW) into other forms of energy through a chemical reaction instead of burning. It involves the conversion of liquid and solid materials into clean and useful syngas (S. Narnaware, 2016), Gasification Technologies Council (GTC) (2014). (N. Berge, 2015). The specifications of gasification technology are as follow:


Reaction Type: Exothermic (R. Atwadkar, 2014).


Feedstock Requirements: Biological and Synthetic origin dry wastes (R. Atwadkar, 2014).

Preprocessing Method of Feedstock: Drying and Pelletization (R. Atwadkar, 2014).[27]

Method: Thermochemical (J. Libra et al., 2011).


Reaction Type: Endothermic B. Basak, (2016.).

Typical Waste Treating Capacity: 10 – 100 tons/day

Feedstock Requirements: Dry mixed MSW without inorganic materials


Permitted Moisture Content of Feedstock: Below 20% D.O. Onyango, and J.W. Kaluli (2016).,

Temperature (°C): 400 – 900 °C (Stantec, 2011).

Residence Time: Slow pyrolysis (Hours – Weeks), Flash pyrolysis (10 – 20 sec) and Fast pyrolysis (1 sec).


Residence Time: Seconds – Minutes


Cost (Capital & O & M): High (R. Atwadkar, 2014).


B. Pyrolysis Technology

Pyrolysis converts carbonaceous materials in to syngas (mixture of CO, H₂, CO₂ and CH₄), mixture of solids (Char) and liquids (Oxygenated oils) by thermochemical decomposition in the absence of oxygen or other reagent H. Raclavska, A. Corsaro, A. Hlavsova, D. Juchelkova, and O. Zajonc (2015), [19], (“Gasification: The waste and energy solution”, 2011). Pyrolysis has three types of reaction depending on the temperature and residence time of the feedstock, named as slow, flash and fast pyrolysis. Slow pyrolysis (conventional pyrolysis) involves low heating rates of feedstock (0.1 – 2 °C/sec), low residence time (sec – few days) and low temperature (about 500°C), with the main products formed are char and tar. Whereas, the flash pyrolysis operates at moderate temperature (400 – 600°C), heating rates above 2°C/sec and less than 2 sec of residence time, with the key products formed are tar and bio-oil. Fast pyrolysis (thermolysis) involves temperatures above 550°C, high heating rates of 200 - 10³ °C/sec and very short residence time, with the quality products being formed (gases rich in ethylene) which can be used for the production of alcohols/gasoline. Mostly fast pyrolysis is used for practical applications due to the nature of its products which is much closer to fossil fuels currently used D.O. Onyango, and J.W. Kaluli (2016), A. J. Marshall (2013).[19]. The specifications of pyrolysis technology are as follows:

Method: Thermochemical (J. Libra et al., 2011).


Reaction Type: Endothermic B. Basak, (2016.).

Typical Waste Treating Capacity: 10 – 100 tons/day

Future Potential: High Potential (J. Libra et al., 2011).

C. Hydrothermal Carbonization Technology

HTC is a thermochemical process which in the presence of water converts the organic substances to hydro char under moderate pressure (2 – 10 MPa) and temperature (180 – 350°C). The hydro char produced exhibit mesoporous textures, high aromaticity structures and moderate calorific value C. He, A. Giannis, and J.Y. Wang. (2013). This process passes the feedstock through sequence of reactions, which includes hydrolysis, dehydration, decarboxylation, aromatization and condensation resulting in the formation of products in gas, liquid and solid (hydro char) states (X. Lu, 2014). The specifications of HTC technology are as follows [19], (X. Lu, 2014), (Council, 2000), C. He, A. Giannis, and J.Y. Wang. (2013):

Principle of Process: Conversion by hot water process.

Typical Waste Treating Capacity: Scalable.

Feedstock Requirements: Wet mixed organic waste.

Preprocessing Method of Feedstock: Shredding and wetting.

Temperature (°C): 180 – 350 °C.

Residence Time: 1 – 12 hour.

Products: Hydro char, Organic compounds (water soluble) and Energy rich gases.

Environmental Issues: Toxic emissions.

Cost (Capital & O & M): High.

Efficiency (%): Carbon Efficiency (90%) and Energy Efficiency (70%).

Product Applications: Soil augmentation, Environmental remediation, Alternative energy source and Fuel source.

Future Potential: High Potential.

Waste Quality and quantity in Oman

The composition, characteristics and generation of waste is an important factor which must be considered to select the suitable WTE technology for Oman A.Bosmans, I. (2013), C. Tatarniuk (2007), M. Samah, (2011). According to the ‘Ramboll Waste Survey’ moisture content of waste in Oman is around 30% (Al-Harrasi, H., Personal Communication, Dec 7, 2016). The organic fraction of waste in Oman is 71.20% and 65.80% of the total MSW in winter and summer respectively, Whereas, the inorganic fraction accounts for 28.80% and 34.02% in winter and summer respectively T. Palanivel, and H. Sulaiman (2014). The generation rates of waste in Oman are given in Fig. 1. The results showed the increasing trend of waste generation with the increase in population over the years. The waste generation correlated positively with the population, whereas when the population is increased, the higher waste generated. Whereas, the composition of MSW in Oman is involves 27% food waste, followed by 21% plastic, 10% carton, 6% glass, 6% textile, 5% park and bio waste, 5% paper, 2% wood with the moisture content of 30% and average energy content of 10MJ/kg (Fig. 2), (Al-Harrasi, H., Personal Communication, Dec 7, 2016), Be’ah (2016).

Discussion and conclusion

This paper discusses thermal WTE technologies which includes incineration, gasification, pyrolysis and HTC. These four thermal technologies require mixed MSW of organic fraction to produce energy. Therefore, depending on the organic fraction of waste in Oman that is 71.20% and 65.80% of the total MSW in winter and summer respectively, and average energy content of 10MJ/kg of MSW, it can be seen that Oman has the potential to set up WTE technology for energy recovery.
HTC has higher future potential when compared with incineration, as it only produces toxic gases whereas incineration along with toxic gases produce ash discharge, out of which the non-useable ash has to be sent to landfills which increases the cost. Also, the energy efficiency of HTC is greater than incineration, hence, making HTC an optimum choice for Oman.

The aim of this paper was to highlight the specific aspects of WTE technologies and waste quality and quantity of Oman. Then based on the condition of waste in Oman an optimum choice of hydrothermal carbonization was proposed.

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References


Be’ah (2016), “Transformation of waste management in Oman”;


C. Tatamiuk (2007), “The feasibility of waste-to-energy in Saskatchewan based on waste composition and quantity”, M.S., University of Saskatchewan,


X. Lu (2014), “Understanding hydrothermal carbonization of mixed feedstocks for waste conversion”, Ph.D, University of South Carolina,