Environmental Energy and Economic Research (2018) 2(2): 137-144
DOI 10.22097/eeer.2018.149284.1044

Refuse Derived Fuel (RDF) Production from Municipal Wastes (Case Study: Babol City)

Maryam Shapoori [a], **Omid Hassanzadeh Moghimi** [b,*]

[a] Department of Natural Resources, Savadkooh Branch, Islamic Azad University, Savadkooh, Iran.
[b] Department of Environmental Engineering, International Campus – Kish Island, University of Tehran, Kish Island, Iran.

Received: 14 February 2018 /Accepted: 4 May 2018

Abstract

Today, with the advancement of technology, turning waste into fuel has been considered as an inexhaustible source of energy production, especially in industries with high energy consumption. The most important of these industries are Cement and Iron Smelting factories. Babol, as one of the largest provinces in the north of the country, has been facing waste management crisis for several years with about 300 tons of waste per day. Currently, more than 90% of the waste collected from this city is landfilled. According to the waste analysis and prediction of RDF (Refuse Derived Fuel) production from refuse materials of the composting line, the landfill was prevented by closing the cycle of waste recycling and processing. In this study, in addition to describing RDF production process, its steps and equipment and taking into account the physical analysis of waste in Babol province, the recycling and processing plans of waste in this city have been proposed by reducing the biological- physical volume (MBWT) and prediction of RDF production. It is expected that the landfill will be completely halted by fully implementing the proposed plan. It is also possible to recycle old landfilled materials through a specific and medium-term schedule and by recovering landfilled materials and injecting them into the system, which of course will bear its own costs.

Keywords: fuel derived from waste, (RDF), waste, Babol, recycling

Introduction

Management of municipal solid waste (MSW) is a vital issue in modern societies, as even the well planned and managed landfills may become problematic as far as the environment and public acceptance are concerned (Pinto et al. 2014). The European Commission requires reduction in landfilling to prevent or reduce, as far as possible, negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, and on the global environment, including greenhouse effect (Council Directive 1999). With the recovery of useful material and energy, MSW can be turned into an asset and resource (Nasrullah et al. 2015). Municipal solid waste management (MSWM) over the years has encouraged the use of many sophisticated technologies and recommended adoption of smart strategies. Nevertheless, MSWM is still facing many challenges as a result of shrinking space for landfills, stringent environmental regulations, and increasing disposal costs (Reza et al. 2013). Energy is one

* Corresponding author E-mail: hasanzadeh_125@yahoo.com

among the human basic needs that drives human life hence extremely crucial for continued human development. It has been pointed that providing adequate and affordable energy is essential for eradicating poverty, improving human welfare and raising living standards worldwide (Kimambo et al. 2014). Nowadays the energy shortage is among the issues of the day and many developing countries supply their needed fuel from other countries. Increase in population and urbanization development has led to increase in waste production and problems relating to urban waste disposal. Lack of space for disposal and emission of pollutants has inspired an incentive to seek better ways to dispose of waste with lower environmental impacts. On the other hand the issue of energy shortage is of high significance and finding a way to provide an alternative, sustainable and affordable energy is essential. One of the ways to reduce fossil fuel demand is to use other energy sources such as clean energy and also energy derived from waste recycling which are taken into account due to their lower price, availability and faster conversion to energy. Applying these methods not only provide the energy required, but also is a supporter of the environment. Today, new methods of waste utilization to produce fuel are very useful and important (Seifolahi et al. 2017).

Fuel derived from waste, briefly called RDF or SRF is the fuel obtained from crushing and drying of municipal solid waste (MSW). This fuel consists of a significant amount of organic elements such as plastics and biodegradable waste. Significant energy is obtained from the combustion of such fuels that is taken into consideration in high-tech industries. Today, one of the waste management approaches is to increase the consumption and marketing of such fuels. Waste materials which are generally reusable as RDF are: tire, rubber, paper, textiles, used oils, wood, plastics, industrial waste, hazardous waste and municipal solid waste (European Commission, 2003). Refused-derived fuel (RDF) is a renewable energy source to produce energy as a replacement of fossil fuels, and analyzing the characteristics of municipal solid waste (MSW) is a critical issue to investigate possible energy sources (Nam-Chol and Kim. 2017). Separation of pre-combustion components from MSW and their conversion to energy is generally done using front-end or back-end methods. These components are mainly plastics and paper (USGS, 2013). In other words, a product can be obtained from the flammable MSW which is more homogeneous and stable than the waste. This material (RDF) is a combination of papers, cardboard, plastic, fabric, leather and wood with a high thermal value, controlled chemical composition, and no bad smell. RDF is the result of separating, crushing, proper shaping (such as bullet, shot, brick, fuel rod, etc.), and clever formulation of various municipal, industrial and agricultural solid waste components. In fact, RDF can be called a kind of secondary fuel (Roknizadeh and Nejati, 2014). The ratio of RDF production to MSW is about 24%, it means that only 240 kg RDF can be extracted from one ton of municipal waste (Nath, 1999). The thermal value of RDF depends on the composition of its constituent elements. Studies indicate that the carbon-hydrogen ratio is constant in extracting alternative fuels from waste, but there is an increase in carbon-oxygen ratios. In fact, extracting fuel from municipal solid waste will change the carbon-oxygen ratios (Beckmann et al. 2012). It should be noted that the energetic valorisation of wastes has an important role in the waste management strategies with legislation and technical notes arising in order to classify and normalize alternative fuels in the electric power plants (De Lemos et al. 2017).

Material and Methods

Production processes

MSW can be converted to RDF using front-end methods that include the following processes:
1. Separation at source
2. Mechanical separation and classification

3. Reducing size (crushing, grinding)
4. Separation and screening
5. Mixing
6. Drying, grading, packaging and storage

Waste-to-energy processes offer an effective way of Municipal Solid Waste (MSW) utilization. They also have great potential to address growing energy consumption issue. One of the ways to effectively reuse waste as energy is the production of Refuse Derived Fuel (RDF) or Solid Recovery Fuel (SRF), and its further utilization by co-incineration or incineration occurring mainly in cement plants (Białowiec et al. 2017).

Different methods can be used to convert MSW to RDF depending on the type of waste (municipal, industrial, etc.) and collection and separation ways.

As shown in Figure 1, a common pre-purification process consists of three main units: destruction, air classification and screening. The MSW is delivered to the facility by packer trucks. Bag-ripping unit, in charge of opening these plastic bags, initializes the presorting process. Ferrous metal is extracted from the MSW stream by using magnets after the bag-ripping unit. Recovered ferrous metal is conveyed to a ferrous storage bin from where it will be recycled. MSW is then shipped into a vertical hammermill shredder through a belt-type conveyor that is followed by an air classifier. Non-ferrous materials, such as aluminum can and other combustibles, as well as the MSW are crushed by the vertical hammermill shredder. However, a manual sorting unit or eddy current separator could be added prior to the vertical hammermill shredder for the recovery of aluminum cans in the future. The air classifier, blowing with a regular air stream from the vertical hammermill shredder, further isolates and separates the inert materials, such as glass, ceramics, and so on, to reduce the content of heavy material in the residual MSW streams. Light materials, passing through the air classifier, are sent into the trommel screen for advanced separation. The dimensions of the openings on the surface of trommel screen can be varied to fine-tune the processing function and assure maximum combustibles recover (Chang et al. 1998).

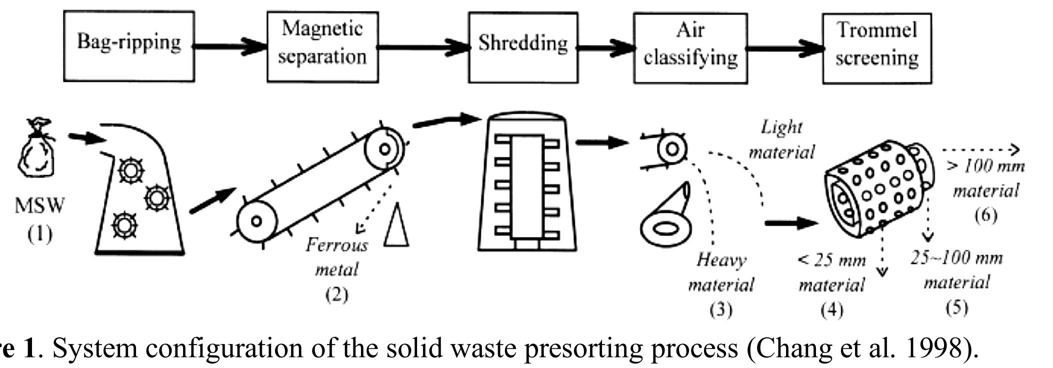

Figure 1. System configuration of the solid waste presorting process (Chang et al. 1998).

In general, the following methods are used to convert MSW and RDF to energy:

1. Fluidized bed combustor
2. Gasification
3. Pyrolysis
4. Coal-fired steam boilers
5. Burning in cement kilns

Incineration technology has been recognized as an effective alternative for solid waste management in the urban and suburban areas with limited landfill space (Chang et al. 1998).

An RDF production line consists of several ''stations'' arranged in series as a train and performing unit operations aimed at separating unwanted components and conditioning the combustible matter in order to obtain an RDF of predetermined characteristics. This is accomplished through successive treatment stages of screening, shredding, size reduction, classification, separation, drying and densification; although the actual line composition will depend from specific site conditions. As a general rule, the MSW treatment line should start with a shredding or screening stage; otherwise the following equipment would suffer from low efficiency. However, if a line starts with a shredder it would suffer from frequent jams because of hard-to-shred components which had not been previously separated by screens, hand sorting, magnetic separation or air classifiers (Caputo et al. 2002).

RDFs contains mainly high quantities of biodegradable material but also a small fraction of plastics. More particularly, RDFs are composed mainly of paper, cardboard, non-recyclable plastics, and other uneven materials (Galhano dos Santos and Bordado. 2018). Quality assurance in the production of RDF demands that, together with an enrichment of the calorific value, highly toxic waste components are selectively separated and concentrated in a small stream to produce high yields of a relatively low polluted fuel. Based on the method of material flow analysis, a process evaluation is developed that considers the aspect of minimizing hazardous chemicals along with classical process data such as yield and product quality (Rotter et al. 2004).

RDF application and its relevant problems

The main application of RDF is to use it as fuel or complementary fuels in boilers and kilns. Some problems are associated with the use of RDF in boilers, which include the following (Roknizadeh and Nejati, 2014):

1. A large percentage of excess air is consumed.
2. Incomplete burning of RDF reduces the thermal capacity of the boiler and produces large quantities of ash per unit of energy produced and also increases the capacity of ash displacement system; In addition, incomplete burning has a reverse effect on thermal efficiency and energy recovery. This is less likely to happen in rotary kilns due to the high retention time.
3. Most RDFs include paper and plastics which have a higher thermal value compared to coal, but with a high percentage of ash (4 to 6 times more than coal) which can damage boilers, also more and more expensive equipment is needed for ash transportation.
4. RDF may contain chlorine which can cause the corrosion of boiler tubes. The existence of small particles of glass and metal in RDF can also cause combustion problems.

With current treatment processes, RDF still contains components which impede the utilization in firing systems or limit the degree of substitution. The content of these undesired components may amount to 4 wt%. These, in most cases incombustible particles which consist of mineral, ceramic and metallic materials can cause damages in the conveying systems (e. g. rotary feeder) or result in contaminations of the products (e. g. cement, chalk). Up-to-date separation processes (sieve machine, magnet separator or air classifier) have individual weaknesses that could hamper a secure separation of these particles (Krüger et al. 2004).

The waste status in Babol City

In terms of geographical position, Babol is located at (52◦ 33' 12") to (52◦ 53' 22") E latitude and (35◦ 54' 49") to (36◦ 33' 52") N longitude of northern Iran. The city is limited to Babolsar and the Caspian Sea from the north, Alborz Mountains from the south, Amol city from the west and to Ghaemshahr and Savadkooh cities from the east. Babol is the most populous city of Mazandaran province which is located at the center of it. It is the capital of Babol County and has 7 cities named Babol, Amirkola, Zargharshahr, Gatab, Khoshroodpey, Galoogah & Marzikola, all of which have their own municipality.The area of Babol county is about 1431 square kilometers and the area of Babol city (excluding privacy) is 31 kilometers. The population of Babol city is 495,472 (247,562 urban population in Babol and Amirkola and 45,000 rural population) which includes 149,320 households. The city of Babol has 1500 administrative (75,702 urban units and 73,618 rural units) and about 13,360 commercial and production units (excluding rural commercial units). Every day, between 250 to 300 tons of waste is produced in this city and after being collected it is transported to a forest area called Anjilsi located 33 kilometers south of Babol. Then, more than 90% of the waste will be landfilled in a non-principled way. Table 1 shows the physical analysis of Babol city's wastes (Babol's Comprehensive Waste Management Plan, 2017).

Table 1. Physical analysis of Babol's MSW (Babol's Comprehensive Waste Management Plan, 2017)

Parameter	Percentage	Parameter	Percentage
Putrescible materials	65.3	Glass	1.2
Paper & Cardboard	8.7	Iron	1.8
PET	1.1	Beverage can	2.3
Rubber	0.5	Wood	1.2
Plastic	7.3	Miscellaneous	9.5
Textiles	1.1	Total	100

Based on the analysis done:

- 66.5% of the wastes are organic food, garden stuffs and wood which can be converted into compost in various ways.
- About 15% (including 2% of recycled plastic bags) are value wastes or the so-called recycled dry waste. In case of waste separation at source, up to 50% of it can be recycled. Otherwise, the efficiency of separation by machines (mechanical processing) will be less than 5% and the rest are added to the materials with a thermal value.
- 15 to 18% of the so-called screened waste (such as plastic bags, some parts of the disposable materials, packaging and textiles waste) have thermal values and are used as alternative fuel energy (RDF) in long kilns of cement and Iron smelting factories.
- 3 to 5% of the total waste volume consist of construction debris, crushed glass, bone and fine plastic material as miscellaneous wastes that can be extracted and separated using equipment like infrared separators.

Conclusion

According to the physical analysis of Babol’s MSW, waste processing can be done within a closed cycle by implementing the processing plan and recycling waste through biological-physical volume (MBWT) reduction to the production of RDF, so that the perishable part of the waste is converted to organic fertilizer (compost) and refused waste is converted to RDF (fuels of long kilns in cement factories) instead of being landfilled. This will stop using landfill site and also generate revenue for the municipality. In addition, the massive waste volume landfilled in the site over the past years will be retrieved and enter the recycling cycle (compost or RDF production) through an advanced engineering-technical process. Technically, the entire proposed process for Babol’s MSW management involves a processing step for composting, a fermentation step, and RDF production step. The composting processing line consists of a shredding machine, 70 mm diameter trammel, three magnets, 60 mm diameter disk screen, a 50 mm diameter vibrating screen and related conveyors. The below-screened waste of these three screens are transferred to fermentation unit by a single conveyor. The above-screened waste of this processing line are separated at two sections of 3D rolling waste and 2D flat waste after passing through a vibrating screen (50 mm diameter). The 3D separated and recycled waste, and 2D wastes with a thermal value, are injected into the RDF production line, in case of RDF consumption in cement factories. The RDF production line consists of a star screen (for the complete purification of organic fine particles) and an RDF shredder (for converting materials into pieces with a diameter of less than 10 cm). If RDF cannot be consumed in cement factories, 2D wastes will be pressed by a press device on the site and preserved. If pressed materials are to be preserved for several years, it is necessary to prepare a coating system for them with polymer materials. Figure 2 shows the overall MBWT process of Babol city up to RDF production stage. The proposed fermentation process for the production of compost is done under the silos, so that the organic materials convertible to compost are stacked as 40-meter long, 5.5 m wide and 2 m high triangular windrows (in existing silos or 90 meters conditioned on the development of current silos) after being transferred into the silo, and will be aerated 8-12 times for about 6 to 8 weeks by a turner. Then, the aerated materials enter into a 30 mm diameter trammel, here the below-screened materials are again stacked as larger windrows and after 3 months will be packed and supplied as a compost with two types of grading (10 and 5 mm). The above-screened wastes (diameter more than 30 mm [up to 80 mm]) are separated by a vibrating screen in 3D and 2D; then 3D materials are separated and 2D materials are injected into the RDF production line. Figure 3 shows the overall proposed process for fermentation phase and aeration of the waste. In the production line of RDF, the input materials are injected into the hopper shredder by a conveyor. RDF shredders are equipped with a system that prevents the bridging of materials in the input chamber. Output materials are driven by the gravity force down the machine and enter into a screw conveyor. This conveyor is designed to separate liquids from solids during the transfer. The solid part is discharged onto the next conveyor.

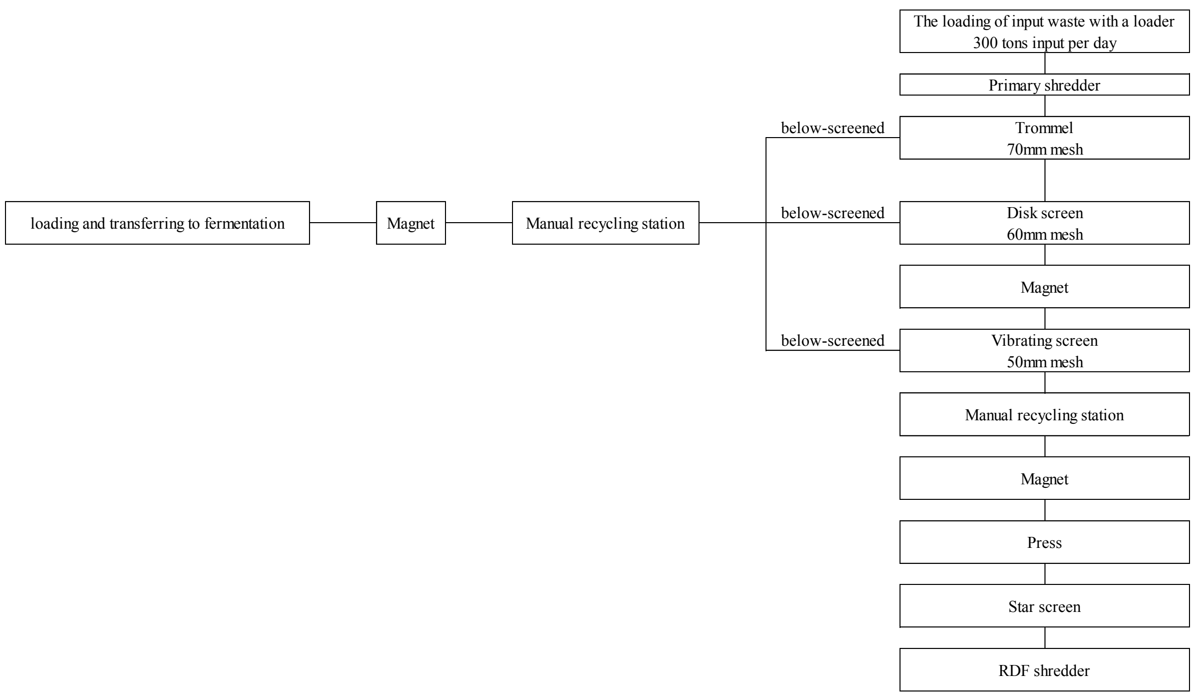

Figure 2. The diagram of MBWT process of Babol city's waste up to RDF production step.

A magnet separator is installed on the conveyer for the separation of iron particles. For further crushing and reaching a desired size, the waste is entered into a secondary shredder in the bottom of which a screen sieve is placed to provide a uniform final material. The secondary spiral and magnetic conveyors are used again after the secondary shredder to separate any iron particles which have not yet been removed. In this section, Eddy current device can also be used in this part to separate non-ferrous metals. At the end of the line, the waste is discharged into the temporary storage chamber. At this stage, mechanical mixing is performed to obtain a homogeneous composition. The final composition is carried from the chamber to the storage center by a conveyor, so it is ready to be used in the accumulation furnace.

According to the results of this research, one of the main issues in Babol compost plant is that the rejected materials from compost plant are buried under the ground. This led to serious environmental problems for the property owners nearby. This paper proposes a method to overcome this issue. We suggest a method for RDF production from the rejected materials of the composting plant. By full implementation of the proposed method, the production cycle will be closed, and we can reach zero landfill. We also propose to recycle old landfilled materials through a specific and medium-term schedule. The process consists of recovering landfilled materials and injecting them into the system, which of course will bear its own costs. A potential market for the RDF produced in the proposed method is Neka Cement Production Plant which is located 70 kilometers east of Babol. In addition to reducing the use of fossil fuels in the cement plant, it can be an income source for the city of Babol.

Acknowledgement
The authors sincerely thank the anonymous reviewers for their helpful comments and highly valuable suggestions that greatly helped to improve the first version of the paper. All of their suggestions were incorporated directly in the revised paper. Authors also would like to thank municipality of Babol for providing basic information about the status of the wastes of the city of Babol and the spiritual support of this research. We are thankful to Department of Natural Resources of Savadkooh Branch.

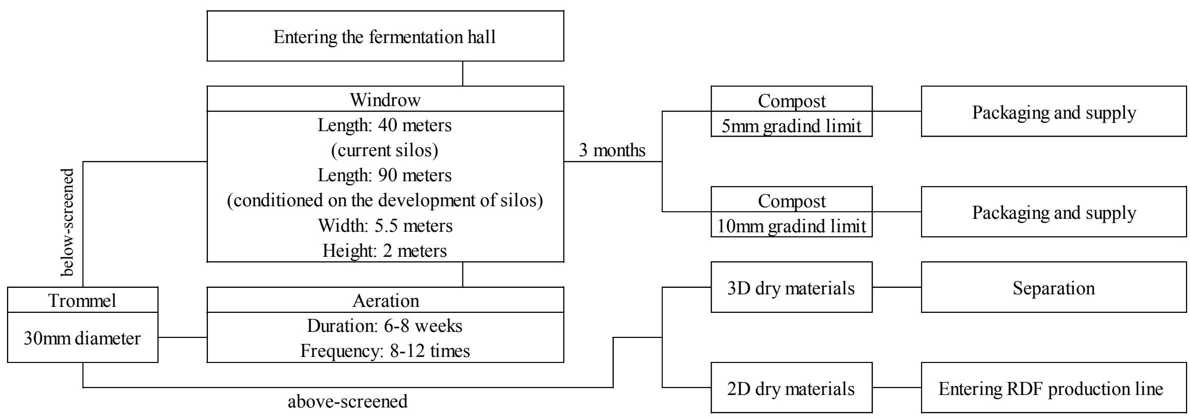

Figure 3. The diagram of the proposed process for fermentation phase and waste aeration.

Reference

Babol Municipality. (2017). Comprehensive Plan for Solid Waste Management in Babol County.

Beckmann, M., Pohl, M., Bernhardt, D. and Gebauer, K. (2012). Criteria For Solid Recovered Fuels As a Subsitute For Fossil Fuels – A review, Waste Management & Research, 30, 354-369.

Białowiec, A., Pulka, J., Stepien, P., Manczarski, P. and Gołaszewski, J. (2017). The RDF/SRF torrefaction: An effect of temperature on characterization of the product – Carbonized Refuse Derived Fuel, Waste Management (2017), Doi 10.1016/j.wasman.2017.09.020.

Caputo, A.C. and Pelagagge P.M. (2002). RDF production plants: I Design and costs, Applied Thermal Engineering, 22, 423–437.

Council Directive 1999/31/EC on the landfill of waste. Official Journal of the European Communities. Available at: http://eurlex.europa.eu/legalcontent/EN/TXT/PDF/?uri=CELEX:31999L0031&from=EN (accessed July 2014).

De Lemos, T., Bras, I., Silva, M.E., Lobo, G., Cordeiro, A. and Faria, M. (2017). Refuse Derived Fuel from Municipal Solid Waste rejected fractions – a Case Study, Energy Procedia, 120, 349-356.

European Commission – Directorate General. (2003). Refuse Derived Fuel, Current Practice and Perspectives, Final Report.

Galhano dos Santos, R. and Bordado, J.M. (2018). Design of simplified models for the estimation of higher heating value of refused derived fuels, 212, 431–436.

Hadi, F. (2008). Methods of converting Waste into RDF, Third National Conference on Waste Management, Tehran, Iran.

Kimambo, O.N. and Subramanian, P. (2014). Energy efficient Refuse Derived Fuel (RDF) from Municipal Solid Waste Rejects: A case for Coimbatore, International Journal of Environment, 3(2), 205-215.

Krüger, B., Mrotzek, A. and Wirtz, S. (2014). Separation of harmful impurities from refuse derived fuels (RDF) by a fluidized bed, Waste Management 34, 390–401.

Nam-Chol, O. and Kim, W.G. (2017). Investigation of characterization of municipal solid waste for refused-derived fuel, a case study, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 39(15), 1671–1678.

Nasrullah, M., Vainikka, P., Hannula, J., Hurme, M. and Kärki, J. (2015). Mass, energy and material balances of SRF production process, Part 3: SRF produced from municipal solid waste, Waste Management and Research, 33(2), 146 - 156.

Nath, K.J. (1999). Solid Waste Management in the Present Indian Perspective, Proceedings of ISWA 1999 Annual Conference, Jonkoping, Sweden.

Pinto, F., André, R.N. and Carolino, C. (2014). Gasification improvement of a poor quality solid recovered fuel (SRF), Effect of using natural minerals and biomass wastes blend, Fuel 117B, 1034–1044.

Reza, B., Soltani, A., Ruparathna, R., Sadiq, R. and Hewage, K. (2013). Environmental and economic aspects of production and utilization of RDF as alternative fuel in cement plants: A case study of Metro Vancouver, Waste Management Resources, Conservation and Recycling, 81, 105–114.

Roknizadeh, J. and Nejati, V. (2014). Technical and economic review of using fuels from waste and worn tires in the Cement Industry of Iran, Iranian Journal of Energy, 17(1), 111-128.

Rotter, V.S., Kost, T., Winkler, J. and Bilitewski, B. (2004). Material flow analysis of RDF-production processes, Waste Management, 24(10), 1005–1021.

Seifolahi, P., Tavahen, A. and Rezvanian, H. (2017). Refused-Derived Fuel (RDF) as an Environmental Solution for Alternative Energy, The 2nd International Conference on Modern Horizons in Agricultural Science, Natural Resources and the Environment, Tehran, Iran.

Ying-His, C., Chen, W.C. and Ni-Bin, C. (1998). Comparative evaluation of RDF and MSW incineration, Journal of Hazardous Materials, 58, 33–45.