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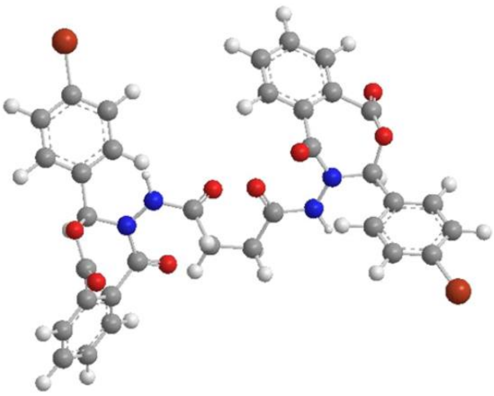

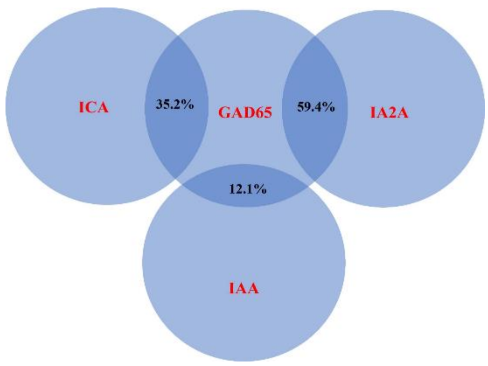

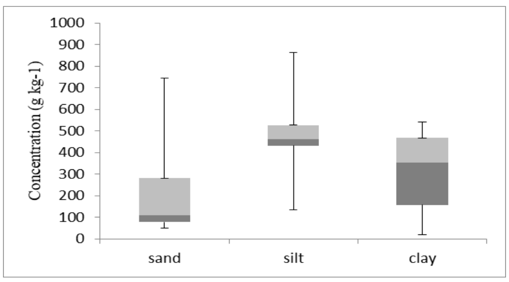

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Refuse-derived fuel(RDF) production and analysis in mechanical-biological treatment (MBT) plant from the municipal solid waste

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Abstract

This study reports on the potential of refuse-derived fuels (RDF), which are produced from Sulaimani Municipal solid waste (MSW) using a biodrying process. Plastic, organic wastes, iron materials, and textiles were used in the formulation of RDF samples. A sample of raw MSW material was collected comprising of 40.6% organic, 29.3% plastic, 6.3% Textiles, 5.1% paper, 3.1% wood, 4.6% glass and stone, 5.2% iron containing materials, and 1.3% others. Physical and chemical properties of the RDF were investigated, including its moisture, ash, total chlorine, and heavy metal content with, calorific value. Based on the experimental results, RDF produced from MSW can be classified into net calorific and total chlorine content values NCV 2 and Cl 4 respectively. In accordance with the European Committee for Standardization (CEN standard), the results of this preliminary investigation of RDF samples made from non-biodegradable and non-recyclable MSW fractions, is necessary to analyze a larger pool of samples in order to project appropriate RDF energy-recovery-enhancing composition.

Introduction

Changing lifestyles and population growth have increased the rate of municipal solid waste (MSW) generation. Globally, treating such large volumes of MSW is a major concern (1,2). In order to manage and treat MSW in an environmentally friendly manner, close attention payed to the amount of generated solid waste. At present, Incineration is a common and important treatment method for MSW, and some studies have investigated the combustion characteristics of real mixed solid waste (3-7). Effective waste management is essential for minimizing environmental damage. Numerous alternative options and approaches are accessible for managing mixed MSW to reduce the remaining amount that must be disposed of in landfills. As a result, modern MSW management systems place a strong emphasis on MSW stabilization before landfilling, energy recovery, and material recycling. The proper management and utilization of MSW could make it a viable source of energy rather than a source of pollution (8,9,10).
Refuse derived fuel (RDF) can be used to convert MSW waste into electricity. RDF are the remaining fractions of material recovery processes that are produced by mechanical-biological treatment (MBT) plants using MSW (11,12). RDF is a different kind of fuel made from MSW that was first described by ASTM standards in 1980s in the United States (13). RDF was initially applied in England prior to the 20th century. Other countries, especially the United States, quickly adopted and developed this technology (14,15). Paper, wood products,

textiles, plastics, and other non-hazardous wastes make up the majority of RDF (16,17). The properties of RDF may be negatively impacted by this heterogeneity, which could result in a decrease in density and calorific value as well as an increase in moisture, ash, and chlorine contents. This could limit the use of RDF in thermochemical conversion processes (18).

Based on the previous reports, RDFs have shown superior qualities comparing to bulk MSW in terms of heating value when considering product (19) and thermal processes (20,21). RDF is now produced and used in countries like Germany, Italy, USA, and the UK to replace fossil fuels (22). Waste conversion into RDFs accomplishes two goals: it decreases the amount of waste transported to landfills and offers alternative fuels for industry (23-25). Many studies have been conducted on RDF analysis based on various parameters of interest, such as biomass content, ash characterization, and aerodynamic classification (26-30). Since RDF has a high energy content, there has been a lot of research on how it behaves in different thermal processes (31).
There are still challenges in collecting and disposing wastes in all the developing countries. (32). Due to regional and temporal differences in MSW, it is difficult to repeat research about real MSW mixtures (33). For instance, plastics may be made of PE, PP, PS, PVC, and PET, all of which have very distinct thermochemical properties (34).

In this study, in order to manage non-biodegradable and non-recyclable MSW in the city of Sulaimani, we evaluated the viability of RDF technology. This includes a number of targets that were studied, including moisture content, ash content, calorific value, total chlorine content, and heavy metal content.

Materials and Methods

Research Area

The city of Sulaimani is located in the Kurdistan region, northern Iraq, with a population of approximately 1.6m. Tanjaro landfill is located approximately 10 km south of Sulaimani and to the west of the main road to Arbat (Latitude: N 35° 33' and Longitude: E 45° 27') (*35*). Energy recovery from non-recyclable materials, such RDF, is done at this location. Since 2020, it has been operating in Sulaimani City.

Figure 1: Map of Tanjaro showing the study area (35)

Figure 2: Biological treatment area (35)

Figure 3: RDF (35)

Input Materials (MSW)

Municipalities are in charge of trash collection, cleanup, and the Tanjaro Landfill site's disposal of created wastes. As new waste (about 750 tons/day of mixed MSW) was being brought in. The RDF Production Process:

For the extraction of RDF from Municipal Solid Waste (ECOCEM) in Sulaimani city, mechanical and biological treatment methods are used which involves the following steps:

- Shredding (120 mm)
- Size screening
- Bio Drying
- Size screening
- Magnetic separation
- Wind shifter
- Shredding

Analyses of waste processing

First of all, all the analyses, ultimate and proximate RDF analyses, were conducted in Eurofins Environment East Freiberg, Germany.

RDF production is being carried out in Sulaimani, no legal limitations in place concerning its physical and chemical properties. After a duration of three weeks, the biodrying procedure has been finalized, fully dehydrated. Samples were gathered from the overall waste, including the coarse fraction (>50 mm or RDF) and the fine fraction (<50 mm). Physicochemical characterizations, namely proximate and ultimate, were conducted. Component analysis of MSW (pre-compressed raw MSW), and mechanical-biological treatment (MBT) to convert MSW into produced RDF was performed. Heavy metal analysis was conducted as well. In order to assure the RDF's quality and minimize negative environmental consequences, the heat value and chemical components, particularly chloride and heavy metals, are typically taken into consideration throughout manufacture (36). Methods and steps for measuring RDF's physical and chemical properties are described below. At least three replications have been performed on all experiments.

Proximate analysis

Moisture content

In accordance with the European Standard DIN EN 15414-3:2011-05, moisture content was assessed. RDF sample was placed into an oven at 105 ℃ for 24h. RDF sample was then cooled and re-weighed to calculate the moisture percentage.

Ash content

The ash content was determined according to following the European Standard (DIN EN 15403: 2011-5). Dry powdered homogenous samples (RDF) were heated to 550°C for 2 hours. A crucible weight changes before and after being placed in the furnace was used to calculate the ash percentage.

Heating Value analysis

Calorific value

The gross calorific value (GCV) of a dehydrated sample was determined using the European Standard DIN EN 15400: 2011, which deals with the calculation of calorific value in solid recovered fuels. Each sample was measured three times for its heating value using a Leco AC-350 calorimeter, and the average value was taken.

Ultimate analysis

Chlorine content

For the subsequent determination of total chlorine content, the sample was digested according to DIN EN 15408:2011.

Heavy metals analysis

Heavy metal content

The sample was then digested in microwaves, diluted and filtered after digestion. The measurement of heavy metal was done using the method of inductively coupled plasma – optical emission spectrometry (ICP-OES) according to the standard (DIN EN 15411: 2011-11, annex C, method D).

Results and Discussion

MSW Composition

Tests were conducted to determine total moisture content and the gross composition of raw MSW samples. For raw MSW sample, total moisture content (50-60w/w%). The average composition and standard deviations of raw MSW material was collected at the three trials (S_1, S_2, and S_3) 40.6% ± 6.34% organic, 29.3% ± 5.6%plastic, 6.3% ± 2.3%Textiles, 5.1%± 1.6% paper, 3.1% ± 1.03% wood, 4.6% ± 2.1% glass and stone, 5.2% ± 1.4% iron containing materials, and 1.3% ± 0.87% others in weight percentage as shown Figure 4. Based on its physical characteristics (Figure 4), MSW is mostly made up of plastic materials that are representative of Sulaimani City lifestyles. Due to the low-cost of plastics, people consume a high number of. MSW composition varies according to climate, lifestyle, economy, and region (33, 34)

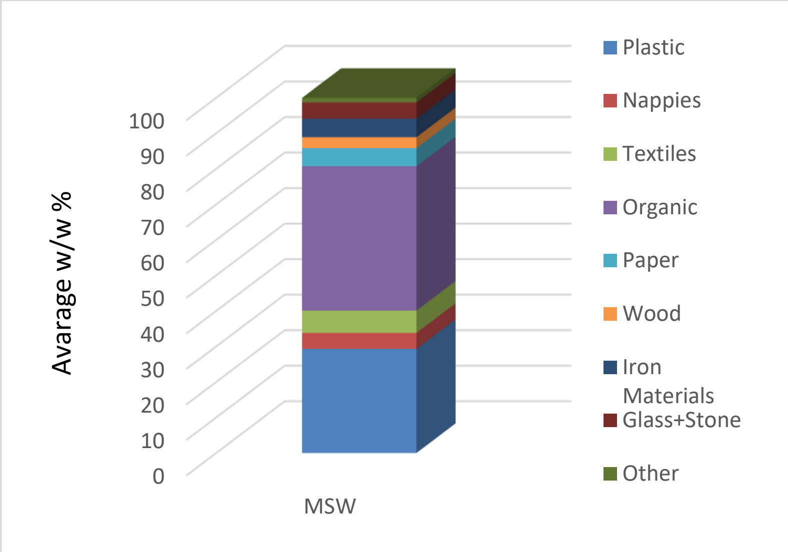

Figure 4: The average composition of municipal waste from Sulaimani City

The study was conducted to determine the characteristics and results of the RDF produced in Sulaimani city. After the biodrying process, samples were taken from the screened material at 50 mm.

Based on the origin of waste materials, type of waste material, and the process applied to produce the RDF from MSW will have varying compositions. The analysis results showed that the average RDF composition and standard deviations consist of six main parts, in the form of plastics (47.7% ± 6.8%), organics (29.1%± 4.88%), papers (5.3% ± 2.01%), nappies (4.7% ± 1.7%), woods (4.3% ±1.08 **%**), textiles (7.2% ±2.76 %) and others (1.7% ± 0.96**%**) as summarized in Figure 5

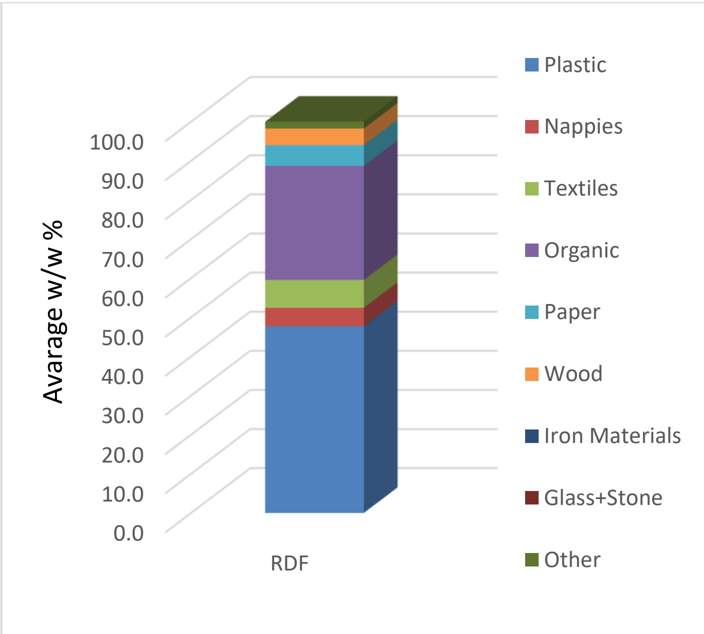

Figure 5: Average Composition of the RDF produced in Sulaimani city

A sorting analysis of RDF indicated that about 81.7% of the fine fraction (< 20 mm) was organic materials. As a result of the additional classification of waste composition, 7.3% is the total organic materials over 50 mm, and 33% under 50 mm and larger than 20 mm, while 81.7 is below 20 mm, as shown in Figure 6.

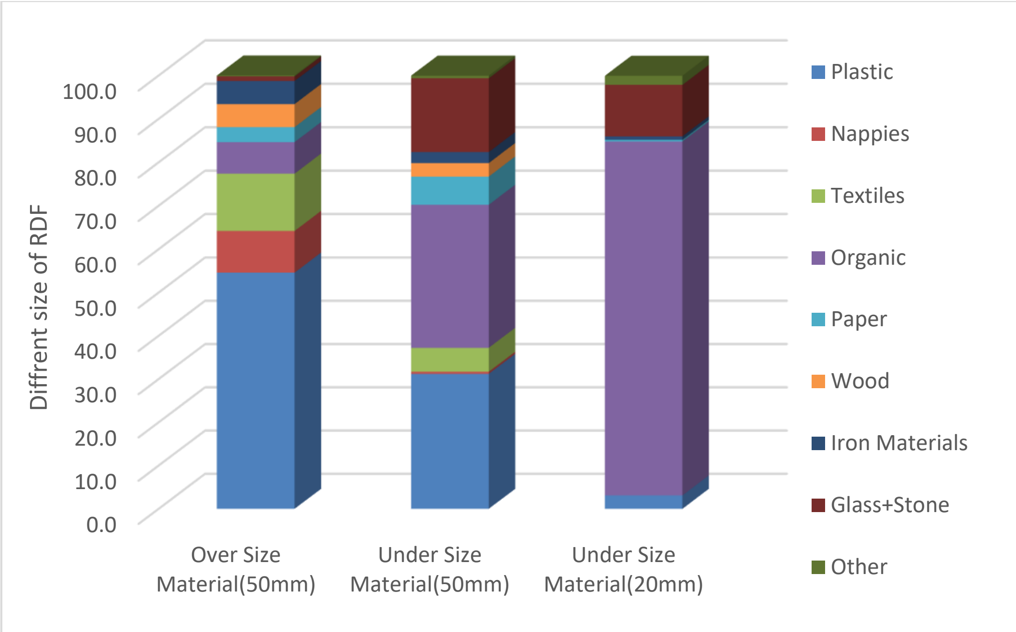

Figure 6: Size distribution of RDF after the biodrying process

As shown in Figure 7, plastic, textiles, nappies, paper and wood have increased in proportion to fresh waste (MSW).

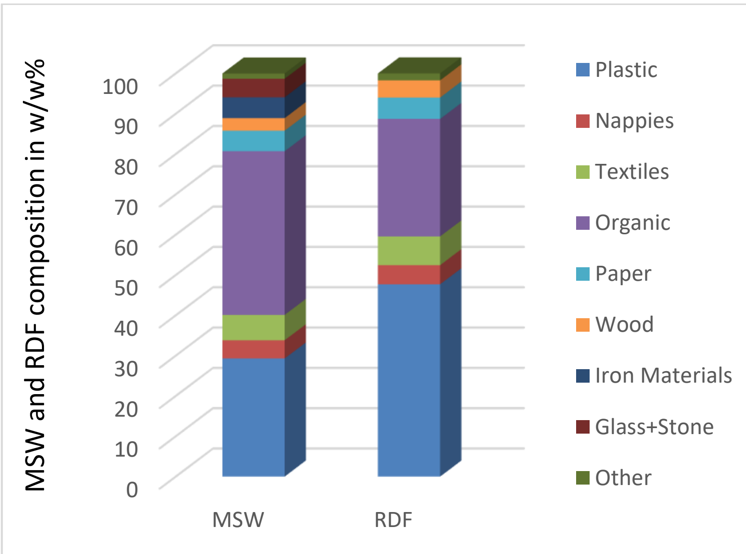

Figure 7: The average characteristics of fresh MSW and RDF after the end of the biodrying process

The RDF is subject to standards to ensure a predefined quality. This type of product has therefore been subject to different quality standards in different countries, including Germany, Italy, and Finland (11).
The composition of RDF produced in Sulaimani city was compared with the typical composition of RDF from MSW produced in other places. (Figure 8).

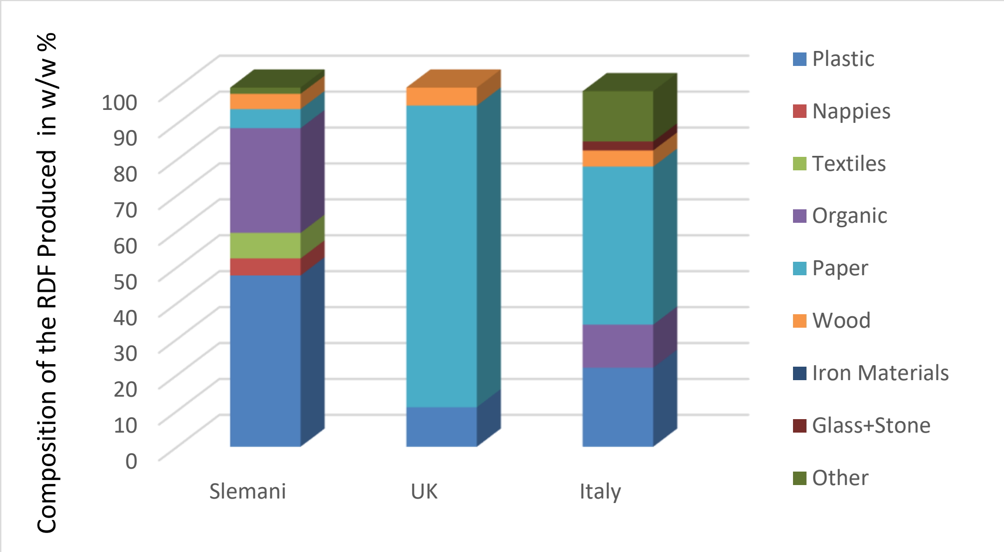

Figure 8: Average Composition of the RDF produced in Sulaimani city compared with the composition set by European countries.

Important features of RDF as a fuel include its calorific value, moisture content, ash content, and chlorine content. The values of these factors and the techniques used to manufacture the RDF will depend on the qualities of the raw waste. The calorific value, low moisture content, and low chlorine and heavy metal concentrations of RDF determine its quality.

Currently, we discuss the results of the basic chemical characteristics of RDF, besides the heating value, other fuel properties, including moisture, chlorine, and ash content. (see table- 1). As a result of pre-treatment and thermal treatment, the moisture content of produced RDF appears to be reduced.

Since raw RDF was collected in July, after several dry and hot months, its moisture content was already low (13.3 wt.%). Fuel lower heating value and biological degradation during storage are negatively correlated with this parameter (37).

Fuel value was significantly reduced by moisture content. Moisture decreased the amount of combustible material per unit (38). The average ash content of the RDF produced in Sulaimani city was 16.67wt%. According to the analyses, ash is mainly derived from paper in RDF samples (31). Plastic bags, other plastics as well, contain low amounts of ash. Decreasing the paper content in RDF and increasing the plastic content, the ash percentage can be reduced (39). There are several advantages of using RDF over raw MSW as a fuel. A major benefit is the high calorific values, which remain relatively constant. A more uniform physical and chemical composition; ease of handling, storage, transportation; reduced pollution، and combustion air requirements are reduced (40).

RDF quality was also limited by chlorine. In the RDF production, plastic material contributed to the concertation of chlorine in the range of 0.56–1.20%w/w. Since it is considered a source of acidic pollutants, it required more attention (41).

Table 1: Characterization of basic proximate parameters of RDF

Parameters	S1	S2	S3	Mean	STD
Moisture% (w/w)	14.6	12.5	12.3	13.13	1.27
Gross calorific value MJ/kg	19.96	21.32	21.48	20.92	0.84
Net calorific value MJ/kg	18.2	19.53	19.68	19.14	0.81
Ash content (550°C)% (w/w)	17.5	17.7	14.8	16.67	1.62
Chlorine (Cl_2) total % (w/w)	1.05	1.83	1.06	1.31	0.45

From the results Table 2, it appears that the RDF generated in Sulaimani city has higher calorific value, less moisture, and an acceptable chlorine content when compared to the RDFs produced in other nations.
In Table 3, heavy metal concentrations in RDF are presented.

Table 2: RDF produced in Sulaimani is compared with RDF produced in several European countries based on available chemical properties (11).

Parameter	This study	UK	Italy
Moisture % (w/w)	13.13	7-25	‹25
Net calorific value MJ/kg	19.1	›18.7	›15
Ash content (550°C) % (w/w)	16.67	12	20
Chlorine (Cl_2) total% (w/w)	1.31	0.3-1.2	0.9

Table 3: Heavy metals content of the RDF produced in Sulaimani

Metals	S1	S2	S3	Mean(mg/kg)	STD
Antimony (Sb)	18	29	33	26.67	7.77
Arsenic (As)	< 0.8	< 0.8	< 0.8	< 0.8	
Lead (Pb)	51	65	54	56.67	7.37
Cadmium (Cd)	2.3	1.9	1.4	1.87	0.45
Chromium (Cr)	81	96	79	85.33	9.29
Cobalt (Co)	5	46	6	19.00	23.39
Copper (Cu)	48	80	38	55.33	21.94
Manganese (Mn)	70	71	73	71.33	1.53
Nickel (Ni)	33	35	26	31.33	4.73
Mercury (Hg)	< 0.07	< 0.07	0.09	< 0.07	
Thallium (Tl)	< 0.2	< 0.2	< 0.2	< 0.2	
Vanadium (V)	4	4	3	3.67	0.58
Tin (Sn)	7	14	7	9.33	4.04

According to Table 4, in every case, they were lower than the other countries' reported ranges. By comparing the results with the EURITS standard, all parameters are within the standard range (11).

Table 4: A comparison of the heavy metal content of the RDF produced in Sulaimani with the quality criteria set by European countries (11).

Metals	Unit	This Study	Italy	Spain	EURITS	Switzerland
Antimony (Sb)	mg/kg	26.7				
Arsenic (As)	mg/kg	< 0.8			10	
Lead (Pb)	mg/kg	56.7	200	<2.500		<100
Cadmium (Cd)	mg/kg	1.9				<5
Chromium (Cr)	mg/kg	85.3	100	<1.500	200	<30
Cobalt (Co)	mg/kg	19.0			200	
Copper (Cu)	mg/kg	55.3	300		200	
Manganese (Mn)	mg/kg	71.3	400			
Nickel (Ni)	mg/kg	31.3	40		200	<10
Mercury (Hg)	mg/kg	< 0.07			2	
Thallium (Tl)	mg/kg	< 0.2			2	
Vanadium (V)	mg/kg	3.7			200	
Tin (Sn)	mg/kg	9.3			200	

Conclusions

In summary, currently, the potential for manufacturing RDF from MSW is being investigated in this study area. According to the EN 1539:2011 standard, the RDF developed in this study as an alternative fuel can be categorized as NCV 2, Cl 4, and is both economically and environmentally sustainable. According to the results, NCVs are approximately 19.14 MJ/kg, and 22.40MJ/kg. According to the results, the RDF generated in Sulaimani city has higher calorific value, less moisture, and an acceptable chlorine content when compared to the RDFs produced in other countries. The produced RDFs were comparable in quality to that of some European nations.

Conflict of interest

The authors confirm that they are not affiliated with or involved in any organization or entity with financial interests.

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