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Evaluation of the Potential Use of Waste Tires as Supplementary Fuel in Jordan Cement Industry

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Abstract

Although scrap tires can cause serious environmental problems, their use as an energy source in cement industry could save considerable amounts of money. The total generated scrap tires in Jordan are estimated to be 7,862,968 per year. The elemental analysis showed that 81% of waste tires was carbon and the average of the measured lower heating value was 33845 kj/kg. Jordan has seven cement factories that produce about 14.1 million tons of cement and consume about 987000 tons of crude oil which costs about 661 million dollars. In this study it is assumed that the weight of an average end-of-life EPU is 8.0 kg and has lost an average of 1.5 kg of tread weight during use. The study analyzed the use of waste tires as supplementary fuel in cement industry in Jordan. Results showed that savings could reach 6.29 million dollars if we used 20% of the generated waste tires per year in cement industry and 31.43 if the whole generated waste tires (100%) were used in cement industry. The impact of using waste tire depends strongly on the price of crude oil in each country. Also results showed that there is a positive correlation between the savings and the price of crude oil.

Indexing terms/Keywords

Waste tires, Elemental analysis, Heating Value, Cement industry and supplementary fuel.

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1. INTRODUCTION

Tires are made from different materials , basically from three raw materials: (1) Latex sourced from rubber trees planted in South East Asia, (2) Chemicals added to the rubber to provide strength and rigidity such as carbon black,sulphur, zinc, wax and antioxidants and (3) Steel, which first is coated to help it adhere to the rubber in the tire, forming 20% of the tires weight.

These three raw materials go through manufacturing process to produce the new brand tires put in the market. After usage , some used tires are replaced with new brand tires and those used tires are sold again in the market to be re -used by other users, which means that they would be used for another period of time until they turn into waste and become unsuitable and reach their end-of-life (EOL). The EOL waste tires are formed in huge amounts and need to be treated adequately and in an environmentally sound manner. It has been reported that the end-of-life tire uses (ELTU) could go in three directions :(1) Energy recovery , (2) Material recovery and (3) lanling [1,2,3]. Figure1 below illustrates the life cycle of tires.

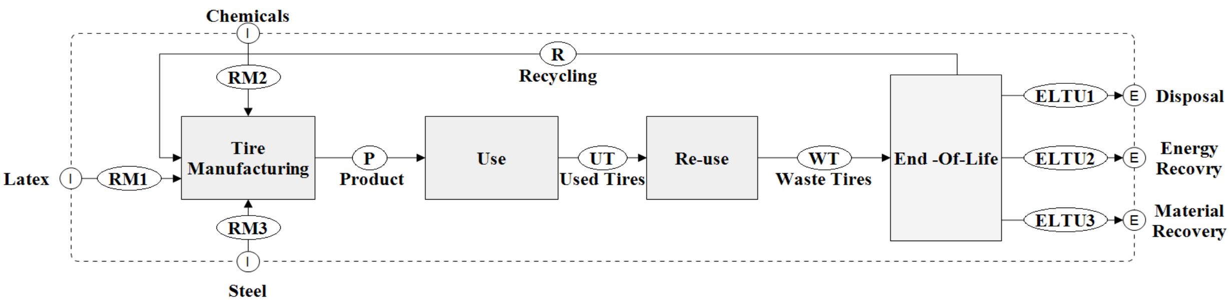

Figure1 Life cycle of tires.

Numerous uses of scrap tires have been introduced, including use in landfills, fuel and energy recovery, septic drain fields, subgrade fill, various rubber and plastic products and asphalt binder (Huang et al., 2007) [1].

Current practices show that residents throw scrap tires randomly in different places such as valleys, road sides, open areas, and waste dumpsites in improper ways taking the means of open fire, and without consideration of risk on human health and environment. Figure 2 is a demonstration of open dumping of waste tires.

Figure 2 Open dumping of waste tires.

In presenting the properties of tires, it can be seen that tire is a rubber article with a complex structure, in which rubber represents approximately (85%) of the weight of car or truck tires. The average tire life is 50,000 km, after which it must be replaced (DiChristina 1994) [2].

This paper will focus on the energy recovery direction and in particular the use of waste tires in cement industry in Jordan. Fuel consisting of shredded tires is denoted as TDF (tire derived fuel) in the international classification. Used tires have a calorific value of 32 MJ/kg, which makes them competitive with other types of fuel, especially with coal, which has a far lower calorific value. The cement industry is one of the greatest consumers of shredded tires, which uses them as an alternative fuel co-combusted with coal; their management is thus waste-free [4-7].

The utilization of alternative fuels can be not only economically profitable but also ecologically beneficial. The most significant benefits are preservation of fossil fuel resources, reduction in the volume of wastes that must be disposed of by other means, and a decrease in the global greenhouse effect (Greco et al. 2004) [8,9].

It has been reported that the supply of tire-derived fuel for cement kiln can be made in two forms: whole tire and processed tire. The advantage of the whole tire is the practicality and simplicity of feeding as seen in Figure 3 below. However the advantage of using processed tire is the higher heating value as the less wire in the tire derived fuel, the higher the heating value [10].

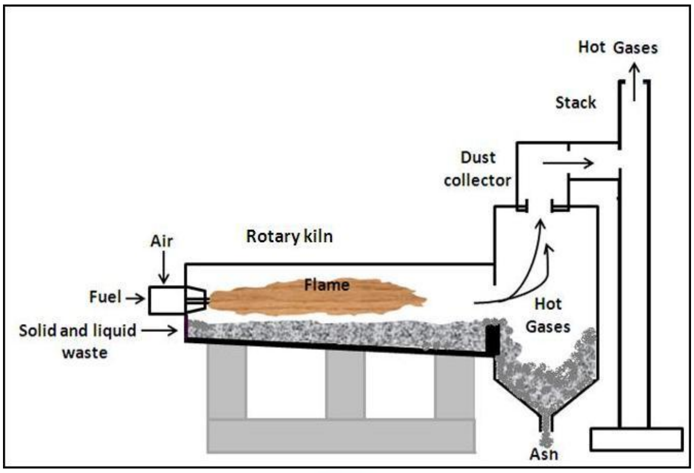

Figure 3 Layout of a typical rotary kiln for burning waste [10]

2. EXPERIMENTAL

2.1 Elemental and chemical analysis of waste tires

It has been reported that the chemical analysis of tyre pyrolysis is a complex mixture of organic compounds of 5-20 carbon with a higher proportion of aromatics. All other compounds such as aromatics, aliphatic, nitrogenated, sulphur (benzothiazol) were also determined in previous studies [11, 12].

Elemental analysis was conducted at the Institute of Power Engineering of Technische Universität Dresden, where C,H, S, and N were measured and the O was defined as the missing mass such that the sum of all components totaled 100% in the testing protocols (100 = Ash + C + H + O + N + S + Cl).

The elemental analyzer was used to measure C, H, and N components in each waste where the samples are burned at 900°C and the resulting flue gases are measured. The S content was measured by a near-infrared detection system (NIR detection system) after increasing the temperature of the resulting flue gas to 1400°C.

The ash content of the samples was determined by burning the samples using a muffle oven heated up to 550°C, following the European Norm (EN 15403), which measures the remaining weight after combustion. Results of elemental analysis of waste tires are shown in Figure 4

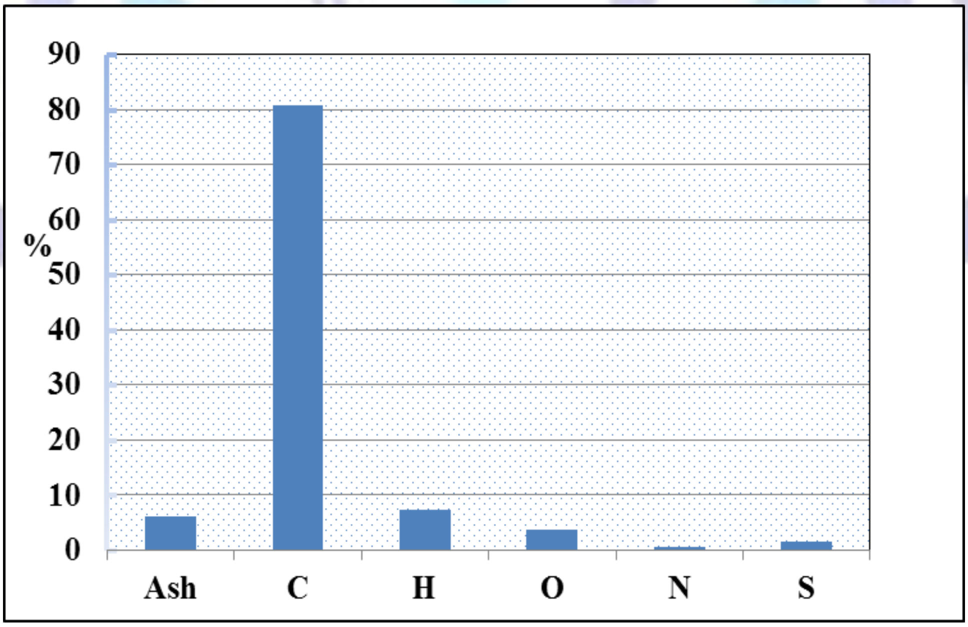

Figure 4 Elemental analysis of waste tires.

The chlorine content was determined following the European Norm (EN 154089), which is based on burning the sample in a calorific bomb and absorbing the generated gases by a chemical liquid, which is then sent to ion chromatography to measure the Cl value.

2.2 Measurements of HHV of waste tires.

The values of HHV and LHV of waste tires were measured at the laboratories of the Institute of Waste Management and Contaminated Site Treatment, using a calorific bomb, applying the European Standards (EN 15400). The HHV and LHV were measured three times for the samples of waste tires. The results are shown in the table below:

Table1 Measures HHV and LHV of waste tires

Trial number	H_{upper}(KJ/Kg)	H_{lower}(kJ/kg)
1	36615	33686
2	37040	34077
3	36528	33771
Average	36728	33845

The average upper heating value is 36.7 Mj /kg. It is not far from plastic wastes seen in Table 2 [13,14] and seems that it can compete with them as alternative energy source.

Table 2 Heating values of some major plastics compared to common fuels.

Items	Calorific value (MJ kg-1)
Polyethylene	43.3 - 46.5
Polypropylene	46.5
Polystyrene	41.9
Kerosene	46.5
Gas oil	54.2
Heavy oil	42.5
Petroleum	42.3
Household PSW mixture	31.8

3. METHODOLOGY

3.1 Generated amounts and costs of scrap tires in Jordan

The standard used by the United States Environmental Protection Agency (EPA) and Scrap Tire Council Management for estimating generation of scrap tires is one tire per person per year [15]. If we apply the same at the current population of Jordan, which was estimated by the department of statistics of Jordan as approximately 6,552,473 million people in 2014 [16], the number of scrap tires would be 6,552,473 million waste tires. If the national rate of tire removal from scrapped vehicles is included, an additional 0.2 tire per capita (1,310,495 tires) would bring the total to 7,862,968 tires.

In Jordan, Retail tire dealers generally charge consumers at a $40.0-50.0 per ton for whole tires. There are no scrap tire processors, and nearly no users of whole or shredded scrap tires, located in Jordan.

3.2 Cement Industry in Jordan

Cement manufacturing involves the combustion of fuels with various raw materials at approximately 2,700 °F (1,500 °C) to produce clinker. Fuel costs and environmental concerns have encouraged the cement industry to explore alternatives to the use of exclusive conventional fossil fuels. The key objective of using alternative fuels is to continue to produce high-quality cement while decreasing the use of conventional fuels and minimizing the impact on the environment.

It has been reported that the costs associated with fuels in a cement plant can be as high as 30 to 40 percent of the total production costs (Mokrzycki et al. 2003) [17].

Jordan has got 7 cement factories with total production of 14.1 million tons. Table 3 summarizes the list of factories with their particular production [18].

Table 3 Jordan cement factories and their production

Factory	(million Tons)
Lafarge Jordan Cement	4.9
Qatrana Cement Co.	2
Modern Jordanian for Cement and Mining	1.2
Saudi Jordanian Co. for Building and Construction Materials	NA
Thab Investment for Building Materials	3
Northern Cement Company	1
Al Rajihi Cement	2
Total Capacity	**14.1**

4. RESULTS AND DISCUSSION

Jordan lacks of significant energy resources and relies heavily on imported crude oil, petroleum products and natural gas to meet domestic energy demand. In 2010, Jordan imported approximately 68,000 barrels per day (bbl/d) of crude oil and 36,000 bbl/d of refined products. In addition, Jordan imported almost 90 Bcf of natural gas in 2010 (International Energy Statistics).

This situation makes alternative energy resources an attractive option to alleviate the lack of natural resources .One of the basic ways of recovering used tires or other used rubber products is to use them as an energy raw material. Cement plants are now able to use, as a fuel, only whole tires. This is possible because of the high temperatures in cement kilns (>1200 °C), which ensure the complete combustion of all the tire components.

The ash and steel cord are permanently bound to the clinker, but this does not seriously impair its physicochemical properties apart from a slightly longer cement binding time and a greater water demand. Moreover, the combustion of tires in cement kilns is environmentally safe because of the much lower emission, compared to coal combustion, of dusts, carbon dioxide, nitrogen oxides and heavy metals (except zinc).

The total cement production in Jordan in 2014, as shown in Table 4, is 14.1 million tons per year. If we apply the required amount of crude oil at the rate of 70 kg crude oil per ton of produced cement [13,14,15], then the total amount of consumed crude oil for cement industry per year will be 987000 tons. If we calculate the total cost at a rate of JD 475 per ton [19], ($669.75 at a rate of JD1 = $1.41), the total cost of crude oil per year will be $ 661043250.

This paper proposes the use of waste tires as supplementary fuel in cement industry in Jordan to alleviate the huge energy bill and to solve a serious environmental issue of waste tires.

This study suggests different scenarios of using waste tires and calculates the savings in the energy bill for the whole production of cement in Jordan (14.1 million tons/year) using crude oil.

The proposed scenarios are to use 100, 80, 60, 40 or 20% of the total generated waste tires in Jordan (7,862,968). It is assumed that the weight of an average waste tire is 8 kg after a loss of 1.5 kg of tread weight during use [20].

To that end we calculated the cost of Kj produced by crude oil and waste tires. The costs are $ 1.59464E-5 and $ 1.18186E-6 consecutively.

The savings resulted for the above different scenarios of the percentage of using waste tires are summarized in the following table

Table 4 Amount of savings as a result of using waste tire as supplementary fuel.

% of generated waste tires used cement production	Equivavalent amount of Energy (Kj)	Cost (million $) when it is produced from waste tires	Cost (million $) when it is produced from crude oil	Savings (million $)
100	2.12898E+12	2.52	33.95	31.43
80	1.70318E+12	2.01	27.16	25.15
60	1.27739E+12	1.51	20.37	18.86
40	8.51591E+11	1.01	13.58	12.57
20	4.25795E+11	0.50	6.79	6.29

As seen in the table the offset of the energy bill could reach up to 31.43 million dollars if we use the whole generated amounts of waste tires and about 6.29 million dollars when we use only 20% of the whole generated waste tires.

5. CONCLUSIONS

Waste tires are considered an environmental problem worldwide and Jordan is no exception. The use of waste tires as supplementary fuel could achieve dual purposes, solving an environmental issue and alleviate the high bill of energy in Jordan. The highest achieved saving could reach 32 million dollars per year if we use all generated waste tires and about 6 million dollars if only 20% of the generated waste tires was used. To that end, it is suggested to establish a collection system in Jordan and create a market of waste tires for supplementary fuel purposes.

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