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Royalty of Using Jordanian Oil Shale as an Alternative Fuel in the Cement Industry

Awwad H. Titi[1], Hani M. Alnawafleh[1], Mohammad K. Dweirj[1,2], and Rami O. Alrawashdeh[1]

[1]*Department of Mining and Mineral Engineering, Faculty of Engineering, Al-Hussein Bin Talal University, Ma'an, Jordan*
[2]*Natural Resources and Chemical Engineering, Tafila Technical University, Tafila, Jordan*

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Abstract

The Jordanian oil shale (JOSh) is considered as a strategic mineral similar to oil. The government of Jordan seeks to earn a new royalty rate from the oil shale extraction industry to cope with the constantly changing fuel oil prices in the world. This paper discusses the royalty rate when using oil shale in the cement industry. The royalty rate is estimated by creating formulas of substitute portions of different types of fuel used in the cement industry. The suggested mathematical equation of the royalty rate determination for each tonne extracted has been calculated, taking into account the stripping ratio and the variability in the oil content percentage in different oil shale (OS) deposits. The purpose of royalty rate determination is to control the mining operations and the quantities of the extracted oil shale. Results indicate that as the portion of oil shale or Petcoke in the mixture increases, the saving rate increases as well. Moreover, the cost of using portions of oil shale or Petcoke in the fuel mixture tends to be less than the cost of utilizing pure fuel oil. The current study recommends using oil shale mixed with fuel as an energy alternative in the manufacturing of cement in Jordan.

Keywords: Oil shale, Jordan, Royalty, Fuel oil, Oil shale ash, Cement industry.

1. Introduction

Jordan has to cope with its growing demand for energy. The implementation of suitable measures to face the increasing demand is urgently needed. The high consumption of imported oil has become a heavy burden on the gross national product (GNP), and an obstacle for the economic development in Jordan.. One important solution could be the use of domestic Jordanian oil shale (JOSh) resources.

Coal is a primary fuel used in the cement industry. A wide range of other fuels such as natural gas, oil, liquid waste materials, solid waste materials, and Petcoke have all been successfully used as sources of energy for firing cement-making kilns, either on their own or in various combinations. Other alternative materials that can be used as thermal energy in the cement maufacture include waste oil, saw dust, tyres, plastics, mixed industrial waste, and alternative fuels biomass (ECRA, 2014).

Up to 30-40 % of the operating costs of cement manufacturing are related to energy consumption; thus, a cement manufacturing plant that takes measures to save the costs of energy has a competitive advantage over cement plants that use traditional fuels (Mokrzycki and Bochenczyk, 2003). The high energy costs prompted major cement producers to look for and use alternative energy sources including oil shale (OS) and Petcoke to reduce the operating costs of the cement production. One tonne of commercial-grade OS contains up to 200 liters (Dyni, 2010), and can be used as an alternative energy source in the cement industry. Up to 6 % of the global OS production is used in cement manufacturing and other industries (Brendow, 2002). An example of the use of OS in the cement industry is that of Estonia (Veiderma, 2003).

In Jordan, the cement industry depends mainly on fuel oil (FO) as a major resource of energy. Over the recent years, oil prices increased dramatically which directly affected the cost of cement manufacturing and production in Jordan. The Jordan Cement Company has already started to look for other alternative energy sources in accordance with the governmental policies in this regard. So far, the only important indigenous source of energy found is the JOSh. The use of JOSh in the cement industry has attracted the Jordanian Lafarge Company since 2006. They ran a pilot experiment to test the use of JOSh along with FO in the manufacturing of cement. The results of their experiment were promising, and they reported 25% possible substitution of FO by JOSh (Jordan Lafarge Cement, 2017).

Jordan has potential OS deposits containing more than 40 billion tons of OS (Alali, 2006). The major JOSh deposits of commercial scale are located near the surface in central Jordan (Figure 1). They are easily accessible from the desert Highway and a substantial part of the infrastructure is already available (Alali, 2006; Besieso, 2007). The JOSh is not true shale (Abed, et. al, 2009; Alnawafleh, and Fraige, 2015). It is kerogen-rich, bituminous, argillaceous limestone that was deposited in shallow marine during the Maestrichtian-Danian periods (Abed, 2000; Pufahl, et. al., 2003; Dyni, 2006). Characteristics and physical properties of the potential JOSh deposits are presented in Table 1.

* Corresponding author. e-mail: hanialnawafleh@ahu.edu.jo

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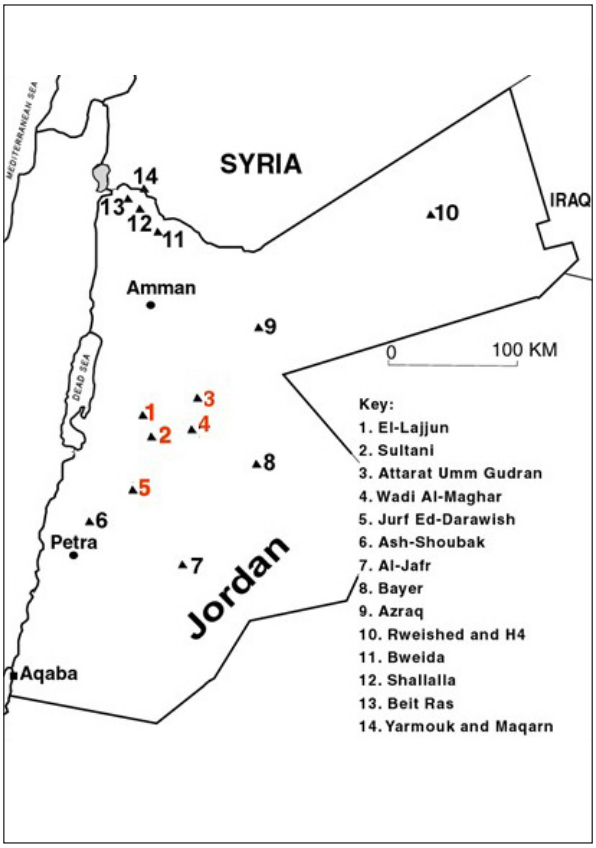

Figure 1. Major Oil Shale deposits in Jordan (Alnawafleh, et al., 2015).

The JOSh deposits in central Jordan have been extensively studied. They represent the potential OS resources for future utilization due to the following factors: They are good in quality and shallow in depth, and the ratio of overburden to OS is very low which makes them favorable for surface mining conditions. Moreover they are located in a thinly- populated area with ease of accessibility, reasonable infrastructure, as well as the availability of adequate amounts of water for the industrial utilization (Alali, 2006; Besieso, 2007; Jaber et al., 2008; Alnawafleh et al., 2015). In addition to the previous factors, and the abundance of JOSh resources in these areas, the supportive business environment offered by the government of Jordan is highly considered. The JOSh reveals local and lateral variability that should be considered in any potential uses of this resource (Alnawafleh et. al., 2015).

This paper highlights the advantage of using JOSh as fuel in the cement industry. More economic utilization of JOSh can be achieved by using both OS energy and oil shale ash (OSA). The most effective way is the use of OSA as a feedstock for the cement production. Studies showed that the addition of about 30% OSA into Portland cement clinker can enhance the compressive strength of the ordinary Portland cement (Al-Hasan, 2006). The royalty rate of JOSh utilization in the cement industry will be calculated. This will be done through the development of royalty equations that will be derived on the basis of the available data on the FO prices, in addition to OS stripping ratio and the percentage of oil content in different JOSh deposits.

Table 1. Specifications of the most important JOSh deposits (Hamarneh, 1998; Alali, 2006).

Description	El-Lajjun	Sultani	Juf Ed-Darawish	Attarat Umm Gudran	Wadi Maghar	Eth Thamad
Geological Reserve (M tonne)	1.3	0.99	8.6	11.3	32	11.4
Area (km^2)	20	24	150	226	29	150
Overburden (O.B) (m)	31	69	47	47	40	400-142
Oil shale (m)	29	32	68	36	40	200-72
Organic materials%	28	25	18	29	20	25
Oil%	10.5	9.7	5.7	11	6.8	10.5
Humidity%	2.1	5.5	4.5	3.25	2.9	2.5
Ash%	54.7	55.5	58.4	53.2	57.5	54.7
Sulfur%	3.1	2.4	2.4	2.6	2.6	3.2
Density (g\cm3)	1.8	1.9	2.1	1.8	2.03	1.8
(kj\kg)	6906	6380	4603	7235	4773	6903
(kcal\kg)	1650	1526	1100	1730	1090	1800

2. Methodology

The data required for the purpose of this study were collected from specific resources including published and unpublished reports, and personal communications. Calculations were made to determine the cost of JOSh extracting, the cost of transporting JOSh from the mine to the factory, and the cost of using and comparing different types of fuel in the cement industry, as well as the royalty rate. Calculation details will be presented in section 3. The expected cost of extracting and transporting one tonne of JOSh from the mine to the factory is 25.34 JOD excluding the saving rate of 1.5 JOD resulting from the use of OSA in the cement industry (Table 2).

one way through which the cement factories in Jordan can save the FO cost can be by using alternative fuel resources such as natural gas, Petcoke, and JOSh. Data were collected to calculate the low heat value (LHV) of each of these fuel types or their mixtures suggested for use in manufacturing cement. The equivalent low heat value (LHV_{eq}) of the mixed fuel is calculated in relation to the FO low heat value (Table 3).

Table 2. The expected cost of JOSh extraction, transportation, and OSA used in the cement industry.

Subject	*Cost (JD/tonne)
Cost of mining operations	4
Cost of crushing	2
Cost of transfer oil shale to the cement factory	4
Cost of Grinding oil shale in cement factory	10
Salaries costs, Maintenance, Diesel for drying and Electricity	3.74
Cost of burning	0.8
Cost of Grinding Cement	0.8
Total Cost	25.34
The advantage of using the oil shale ash	1.5
Cost of one tonne of oil shale	

** Cost data based on some personal communications (11/11/2017) with different Jordanian mining companies.*

Table 3. A comparison between the costs of OS with different kinds of fuel, taking into account the energy content of each kind.

Items	Unit	Fuel Oil *	Natural Gas *	Petcoke **	JOSh***
LHV(Low Heat Value)	Kcal/Kg	9600	11782	7500	1500
LHV$_{eq}$(equivalent to mixed fuel)	Times	1	0.81	1.28	6.4
Average Fuel oil price, 2016	JOD/ Ton	254	514.2	116	23.84
Comparative prices of fuel type	JOD/ Ton	254	391.60	148.48	152.58
Saving	JOD	0	---	105.052	101.42
Saving per 1ton raw oil shale	JOD/ Ton	---	---	---	16

Fuel oil and natural gas prices according to MEMR (2016) and Statista (2017).
*** Price and calorific value of Petcoke by Personal Communication (11/11/2017) with the Crushing Unit Manager of Al-Rashadieh Cement Factory.*
**** Based on data reported by Alali (2006).*

The average crude oil price annually from 2004 to 2017 is shown in Figure 2. Data of 2017 is used for the purpose of calculation the saving rate using different ratios of JOSh and Petcoke with FO as a mixture, in addition to the royalty rate.

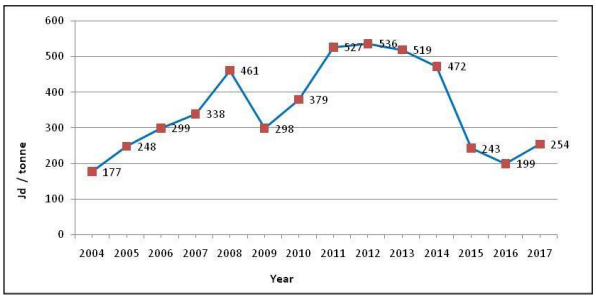

Figure 2. Average crude oil price annually from 2004 to 2017 released by the Organization of the Petroleum Exporting Countries (OPEC) [in JOD per metric ton, note:1 U.S Dollar equal 0.7 JOD] (Statista, 2017).

3. Discussion and Results

3.1. Saving Rate Calculation

Natural gas is not utilized in Jordanian industries due to the resource unavailability in Jordan and the special setup needed for the carrying and using this resource. Due to the repeated disruption of the pipeline that carries the imported Egyptian natural gas as a result of unstable regional conditions, and the need for special equipment to use gas as fuel in the cement industry all make the utilization of natural gas in the cement industry in Jordan quite unfeasible. However, the use of Petcoke can be promising taking into consideration that cement companies must import it from abroad as it is not produced locally. Because there are large reserves of good quality JOSh in Jordan and because of the ease of the extraction of JOSh through surface mining methods, and the possibility to use OSA in the cement industry, all make the use of JOSh as an energy resource in the cement industry a very good option. Studies show that OSA is a very good additive to cement (Smadi and Haddad, 2003).

Tables 4 and 5 show the average FO prices used in the cement industry, in addition to the calculation of the saving rate after using different ratios of JOSh and Petcoke with FO as a fuel mixture in order to save the cost of fuel used in the cement industry. Data indicate that the cost of JOSh and Petcoke used in the mixture is less than that of the FO. Moreover as the JOSh and Petcoke ratios in the mixture increase, the saving rate also rises.

Table 4. Calculation of the saving rate using different ratios of FO and OS mixtures.

FO Price JOD/T *	Gov. OS price JOD/T	OS%	OS price JOD	OS weight Kg	FO%	FO price JOD	FO weight Kg.	OS and FO mix. price JOD/T	Saving Rate JOD/T
254	131.82	5	7	320	95	241	950	248	6
254	131.82	10	13	640	90	229	900	242	12
254	131.82	15	20	960	85	216	850	236	18
254	131.82	20	26	1280	80	203	800	230	24
254	131.82	25	33	1600	75	191	750	223	31
254	131.82	30	40	1920	70	178	700	217	37

** Based on FO latest prices reported in MEMR (2016) and Statista (2017).*

Table 5. Calculation of the saving rate using different ratios of FO and Petcoke mixtures.

FO Price JOD/T *	Petcoke Price JOD/T	Petcoke%	Petcoke Price JOD/%	Petcoke weight Kg.	FO %	FO price JOD	FO weight Kg.	Petcoke and FO mix. price JOD/T	Saving Rate JOD/T
s254	148.48	5	7.4	64	95	241	950	249	5
254	148.48	10	14.8	128	90	229	900	243	11
254	148.48	15	22.3	192	85	216	850	238	16
254	148.48	20	29.7	256	80	203	800	233	21
254	148.48	25	37.1	320	75	191	750	228	26
254	148.48	30	44.5	384	70	178	700	222	32

** Based on FO latest prices reported in MEMR (2016) and Statista (2017).*

Figure 3 shows a comparison between the use of FO mixed with different ratios (5-30%) of JOSh and Petcoke with pure FO used in the cement industry. Results show that the savings are charged when using both JOSh and Petcoke in cement industry. The saving rates after using different ratios of FO and JOSh mixtures are slightly higher than that obtained when using different ratios of FO and Petcoke mixtures.

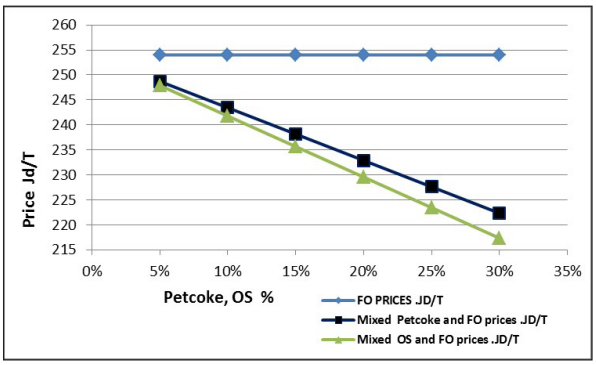

Figure 3. Comparative prices of FO and FO with JOSh and Petcoke mixtures.

3.2 Royalty Rate Determination

The government of Jordan has regarded JOSh as a strategic resource and has decided to put in place an appropriate mechanism for the royalty determination required of the mining companies to extract one tonne of JOSh. For this purpose, a concept for calculating the required royalty rate will be developed, taking into account the JOSh deposit conditions in various areas in Jordan including the overburden thickness above the JOSh (stripping ratio), and the oil content percentage in each area. In order to control the mining operations and the quantities of the extracted JOSh so that the companies will not be able to exclude quantities of extracted low-grade OS, it is necessary to link the royalty rate with the global FO price.

To formulate the royalty equation in relation to the different global FO prices, the FO prices are plotted against suggested progressive ratios (Figure 4). It is considered that the lowest FO price from which the royalty rate can be calculated equals 200 JOD/t which is weighted as 1%. As the suggested progressive ratio increases; the price of FO increases as well. Therefore, the developed royalty ratio equation is:

Y= 0.0148 X – 2.02 ……..…….. (1)

Where; Y: Royalty%, X: FO price.

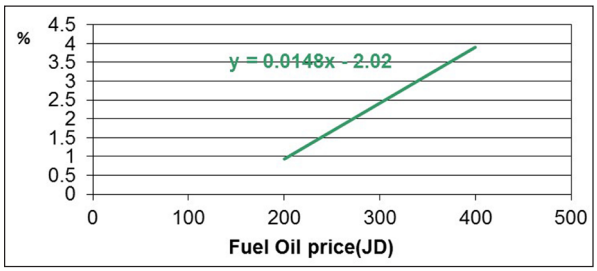

Figure 4. Royalty equation developed through the connection between different FO prices and suggested progressive ratios.

The difference in the stripping ratio and the oil content percentage in different JOSh deposits (areas) should to be taken into account in the process of royalty calculation. Firstly, for the purpose of variability in oil content, the highest percentage of oil content in the JOSh is 11% reported in Attarat Umm Ghudran deposit (Alali, 2006). This highest percentage of oil content is weighted as 100%. Therefore, the oil content in other deposits is calculated in relation to this ratio (Table 6). Secondly, for the purpose of variability in stripping ratio (SR), the standard SR value (1:1) for OS is found in Wadi Maghar deposit which is calculated from the overburden and JOSh thickness (data shown in Table 1). The standard SR value (1:1) is weighted as 100%, therefore, SR in other deposits is calculated in relation to this ratio (Table 6).

Table 6. The stripping ratio (SR) and oil content percentage calculation.

No.	Area/ JOSh Deposit	Oil content %	Oil content percentage compared with the highest percentage	Stripping Ratio (SR)*
1	Attarat Umm Ghudran	11	100	1.3
2	El-Lajjun	10.5	95.5	1.1
3	Eth Thamad	10.5	95.5	2
4	Sultani	9.7	88.1	2.2
5	Khan AzZabib	6.9	62.7	1.6
6	Wadi Maghar	6.8	61.8	1
7	Juf Ed-Darawish	5.7	51.8	0.7

**Calculated on the basis of the data reported in Table 1, where SR = O.B thickness/OS thickness.*

Based on previous assumptions, the government royalty ratio equation will be:

Y = (0.0148X-2.02)*(Oil content %) / SR .....(2)

Where; Y: Royalty %, X: FO price, SR: Stripping ratio.

As shown in Table 7, and based on equation (2), the royalty ratio is calculated for all deposits in relation to the different FO prices. Based on that, the royalty rate (JOD/t) can be obtained by equation (3). The results are shown in Figure 5.

Y (JD/t OS) = Y% * X .....(3)

Where; Y: Royalty %, X: FO price.

Table 7. Government royalty of different JOSh deposits according to equation (2).

	Area/ JOSh Deposit	Oil content percentage	SR	Y%, Oil price 200 J/t	Y%, Oil price 250 J/t	Y%, Oil price 300 J/t	Y%, Oil price 350 J/t	Y%, Oil price 400 J/t	Y%, Oil price 450 J/t	Y%, Oil price 450 J/t
1	Attarat Umm Ghudran	1	1.3	1.41	2.89	2.89	3.63	4.37	5.11	5.85
2	El-Lajjun	0.955	1.1	1.21	1.95	2.69	3.43	4.17	4.91	5.65
3	Eth Thamad	0.955	2	2.00	2.74	3.48	4.22	4.96	5.70	6.44
4	Sultani	0.881	2.2	2.15	2.89	3.63	4.37	5.11	5.85	6.59
5	Khan AzZabib	0.627	1.6	2.17	2.91	3.65	4.39	5.13	5.87	6.61
6	Wadi Maghar	0.618	1	1.71	2.45	3.19	3.93	4.67	5.41	6.15
7	Juf Ed-Darawish	0.518	0.7	1.47	2.21	2.95	3.69	4.43	5.17	5.91

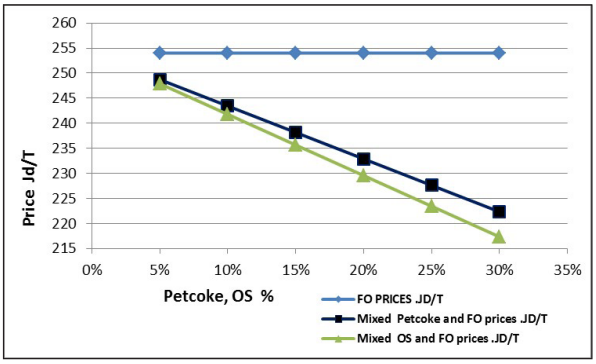

Figure 5. Royalty (JD/t) for major JOSh deposits.

Conclusion

In order for the Jordanian cement factories to save the fuel oil cost in cement manufacturing, they have to depend on alternative fuel resources such as natural gas, Petcoke, and oil shale. In Jordan, the energy sector depends primarily on imported crude oil. However oil shale is the only available indigenous fossil fuel resource. Jordan is a country with a large volume of Oil Shale reserves. One good strategy for the companies that manufacture cement in Jordan is the use of oil shale to partially substitute fuel oil in the cement production. In short Oils shale will be the alternative source of energy in the Jordanian cement factories. Also, oil shale ash is considered as an important additive raw material in cement. The results of this study show that the expected cost of one tonne of oil shale extracted from the mine and transported to the cement factory is 25.34 JOD (deduct 1.5 JOD saved after using oil shale ash in the cement industry). The cost of oil shale or Petcoke used in the fuel mixture is less than the cost of using pure fuel oil. As the oil shale or Petcoke ratios in the mixture increase, the saving rate will increase as well. The government royalty rate is calculated in order to control the mining operations and the quantities of the extracted oil shale. Therefore, the low-grade oil shale will not be excluded. By taking into consideration the variation in oil content percentage and the stripping ratio, the royalty equation gurantees justice for both the Jordanian government and the mining companies as well,. The formulated royalty equation can be applied in all oil shale mining projects in Jordan.

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