Economic Evaluation of Waste Lubricating Grease Recycling Technology

Motshumi Diphare, and Edison Muzenda

***Abstract*—**The aim of this study was to evaluate the feasibility of using solvent extraction to recover base oil form waste lubricating grease. Waste lubricating grease generation was used to determine the potential market size based on feed stock and oil demand. A financial economic model was applied to investigate the feasibility of the recycling technology. Various input and output data were based on experimental results and some were extracted from literature. For 800kg/day treatment plant, an investment of $ 615,439.27 is required with a potential return on investment of 40%. The plant can bring sustainable job creation while producing 160,000 litres per annum of base oil at a cost of $1.47/litre. This investment has the potential to address the environmental and economic challenges of waste lubricants management.

***Keywords*—**Economy, Oil, Profit, Production cost, Revenue, Waste grease

I. Introduction

RECENT hikes in crude oil prices have necessitated the need for alternative sources of mineral oils. Oil price changes could harm economic activities due to the effect they exert on transportation, production costs, economic uncertainty and disposable income [1]. Reference [2] reported that oil is more than an energy source as it is vital to today's economies because of its various applications as a transportation fuel, portable and flexible carrier and a feedstock for various manufacturing and industrial processes. History has shown that spikes in the price of oil have been the primary cause of most recessions [2]

Lubricating greases consist of a thickening agent dispersed in mineral or synthetic oil, forming a colloidal suspension [3]. The main purpose of lubricating grease is to reduce friction between moving parts of various equipment or machinery. The use of lubricants minimises material wear and contributes to improved efficiency of equipment or machinery, fuel and energy savings. During operation, grease suffers mechanical and thermal degradation, particularly for operation at high speeds and temperatures. In some cases this can lead to a loss of lubricating capacity and failure of the bearing [4]. Subsequently, it is regarded as waste and it must be disposed with precaution due to the toxicity of its nature.

Waste disposal is an option when there is no waste utilization and minimization route. The disposal is accomplished by burning (without energy recovery) and land filling [5]. Disposal of waste has been the main waste management strategy over many decades. Presently, this legacy of the past is a major environmental problem [6].

Waste material may migrate into the surface water or groundwater resources, where it can be ingested and harm the human body and other living organisms. It may enter the food chain via uptake by plants and consequently by human, with possible long lasting impacts on human health. The gradual decomposition of waste materials generates toxic gases such as methane and carbon dioxide. Also space for landfills is either limited or unavailable and on the other hand, open burning and inefficient combustion of waste materials produce air pollution and toxic residues. In addition, the clean-up and remediation technologies required to reduce the environmental consequences of waste disposal are very expensive and technically complex [7].

The consumption of automotive lubricants is substantially high as the number of vehicles has steadily increased in the last 15 years. This is primarily due to the increase in the number of privately owned passenger cars. It is expected that the demand for automotive lubricants will experience a steady growth as the vehicle industry rapidly grows [8].

Reference [9] reported that in Croatia only 56% of the consumed oil is collected as waste oil for proper handling. This is evident that there is a significant amount of oil which is lost to the environment, thus loss of valuable hydrocarbon resource.

There is a search for alternative sources of oil due to increasing crude oil prices and depletion of reserves [10]. Despite several advantages of an effective lubricant recycling process, experience has shown that there are several obstacles, which hinder the development of effective recycling markets. There is not enough awareness about recycled products and confidence in the quality of recycled oil.

Recycling is widely regarded to be environmentally beneficial and conducive to sustainable economic development. It mitigates resource scarcity, decreases demand for landfill space and generally involves savings in energy [11]. This can be achieved by investing in recycling technologies through building recycling plants. However, plants are built to make a profit, and an estimate of the

Motshumi Joseph Diphare is with the Department of Chemical Engineering, Faculty of Engineering and the Built Environment, University of Johannesburg, Doornfontein, Johannesburg 2028, (email: dipharej@gmail.com).

Edison. Muzenda is a full Professor of Chemical Engineering, is with the Department of Chemical Engineering, Faculty of Engineering and the Built Environment, University of Johannesburg, Doornfontein, Johannesburg 2028, South Africa, Tel: +27115596817, Fax: +27115596430, (Email: emuzenda@uj.ac.za).

investment required and the cost of production are needed before the profitability of a project can be assessed [12]. As a consequence, the aim of this study was to estimate production costs, including inputs and taxes, as well as evaluating economic viability of a recycling process.

II. Methodology

Detailed cost calculations were conducted for a pilot plant to extract base oil from waste grease with a feed capacity of 800 kg per day. Waste grease was assumed to be delivered by an approved waste collection company to recycling facilities. A suitable process design was considered taking into account the availability of waste grease, product demand and the market. All capital equipment were specified to the expected process duties, electrical and civil requirements. The technology offers a modular reactor to thermally degrade 100kg of grease per batch. This is accompanied by an extractor for sludge removal. The detailed process was discussed by the authors [13], Fig. 1

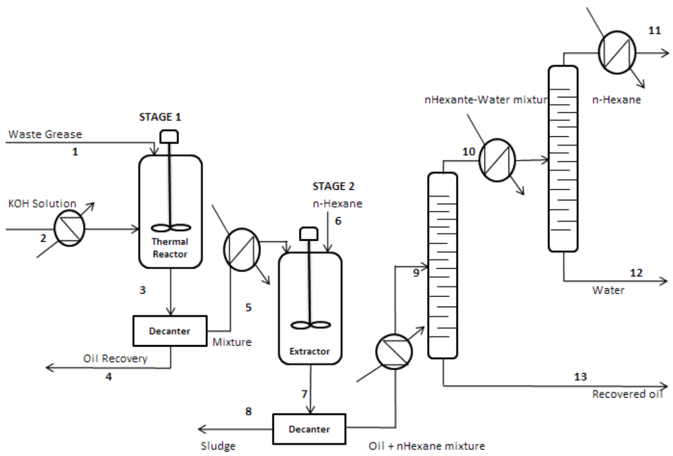

Fig. 1 Process flow diagram of waste grease treatment process

Budget estimates for all capital equipment and reagents were requested from individual manufacturers and suppliers. Table I presents materials and energy balances for the process. This data was used to quantify utilities and products. The cost model was carried out on the basis of 8 hours per day operation. The model was formulated based on a project life cycle of 10 years. Factors such as depreciation, debt repayments, fixed and variable costs were taken into account.

The treatment plant requires water for cooling, steam production and condensation of the recovered solvent. Steam was the heating medium. The required power generation is supplied by the responsible municipality at a predetermined industrial rate.

III. Results and Discussion

The economic model was based on 10 years project life, 8 hours working shift, 1 shift a day and 20 working days per month. Table II presents the model assumptions. The plant cost was based on South African Rand at an exchange rate of US$1: R 9.80 (date, 07 October 2013). A 100% senior debt funding was used with a total interest rate of 9% per annum. Company tax rate and value added tax of 29% and 14% respectively were taken into account. The model also allowed for fixed and variable cost including 4% per annum maintenance fee as a percentage of installed equipment as shown in Table III.

TABLE I
Material and Energy Balances

	Mass balance	Energy balance	Rate/Fee
Waste grease	100 kg	25.2kW	
Water	85 L	34.54kW	0.01 $/L
KOH	15 kg	10.74kW	1.87 $/kg
Diluent	115.3 L		2.09 $/L
Waste sludge	50.28 kg		0.16 $/kg

The unit cost for electricity was obtained from [14]. Water rate of R0.06/ L was obtained from [15]. Prices for hexane and potassium hydroxide rates were requested from Rochelle Chemicals. The current market price of mineral oil 1.47 $/L was used to calculate revenue. The reagents consumptions such as hexane and KOH were calculated by material balance based on a 100kg waste grease batch.

Profitability analysis was also done for the whole project period. Costs of producing grease derived oil included fixed costs and variable cost including 4% per annum maintenance fee of fixed capital investment. The total capital investment of the project was $ 615,439.27 as shown in Table III. The fixed capital costs were estimated by using the Lang Factor Method. This method estimate fixed capital cost as a function of the total purchased equipment cost.

TABLE II
Assumptions Used for this Model

Description	Units	Value
Annual Working Hours	Hours/year	1,920
Plant Estimate Down Time	Hours/year	480
Plant Available Time	Hours/year	1,440
Actual Plant Capacity	Kg/year	192,000
Exchange Rate	R/US$	9.80
Project Period	Years	10
Depreciation Period	Years	10
Capital Financing Period	Years	10
Margin on Investment	% per annum	3
Debt	% Capital	1
Bank Finance Fee	% on debt	2.13
Actual Annual Production	L/year	160,000
Available Plant Capacity	L/year	144,000
Actual Production	L/day	666.70
Input Cost		
Electricity Cost	$/kWh	0.067
Water Cost	$/L	0.0061
Cost of Potassium hydroxide	$/kg	1.87
Cost of Hexane		2.09
Power requirement	kWh/hr	70.48
Water Consumption	L/hr	85
Hexane Consumption	L/hr	13.84
Output Cost		
Sale of Waste Grease Derived Oil	$/L	1.47
Waste gate fee	$/kg	0.138

Straight-line depreciation method was used to calculate depreciation of assets over 5 years. This method subtracts the salvage value from the purchased price of assets then divide it by the total estimated life in years. Senior debt repayments of $ 184,168.02 were calculated using 100% senior debt funding over a 10 year project period at 9% interest rate per annum with company tax rate and value added tax of 29% and 14% respectively.

TABLE III
ANNUAL PRODUCTION COSTS FOR THE RECYCLING TECHNOLOGY

Description	Amount
Capital Investment	
Total physical plant cost	$ 369,079.02
Fixed capital cost	$ 535,164.58
Working capital	$ 80,274.69
Total investment required	$ 615,439.27
Variable costs	
Raw materials	$ 109,373.18
Miscellaneous material	$ 1,712.53
Utilities	$ 5,169.80
Sub total	$ 116,255.50
Fixed costs	
Maintenance	$ 21,406.58
Operating labour	$ 8,571.43
Laboratory costs	$ 1,285.71
Supervision	$ 8,571.43
Plant overheads	$ 3,428.57
Capital charges	$ 53,516.46
Insurance	$ 5,351.65
Local taxes	$ 10,703.29
Sub total	$ 112,835.12
Direct production cost	$ 229,090.63
Sales expense	$ 22,909.06
Research and Development	$ 2,989.56
Sub total	$ 25,898.62
Annual production cost	$ 251,999.69
Production cost ($/kg)	$ 0.87

Two revenue streams were from sales of grease derived oil and waste gate fee at $1.47 per litre and $ 0.138 per kg respectively as shown in Table II. Table IV shows the two revenue stream projections over a period of 10 years. The internal rate of return was found to be 40%.

The project cash flow diagram in Fig. 2 is required to study the project finance from the feasibility studies phase till the operation phase in order to compare the economics of the project [12]. The cumulative cash flow provides indicators for payback period, profit, and the maximum capital. Point A to B indicates the investment period it will take to design the plant with a value of $30,771.96. B to C indicates the heavy flow of capital required to construct the plant. The project experiences negative cash flow as there is no income in these stages. The operation stage starts at point C where revenue is generated, hence the cash flow slope starts to increase. Cumulative cash flow remains negative until the investment is paid off at point D which is the breakeven point or payback time. It will take 3 years and 8 months to recover initial project costs. The summation of cash in and cash out at point D equals zero. A positive value of $250,281.79 at point E indicates profit where the project is considered to be viable.

TABLE IV
REVENUE STREAMS

Period (Year)	Oil Derived Fuel	Waste Grease Gate Fee	Total Revenue
2	$ 235,102.04	$ 26,448.98	$ 261,551.02
3	$ 250,148.57	$ 28,141.71	$ 278,290.29
4	$ 266,158.08	$ 29,942.78	$ 296,100.86
5	$ 283,192.20	$ 31,859.12	$ 315,051.32
6	$ 301,316.50	$ 33,898.11	$ 335,214.60
7	$ 320,600.75	$ 36,067.58	$ 356,668.34
8	$ 341,119.20	$ 38,375.91	$ 379,495.11
9	$ 362,950.83	$ 40,831,97	$ 403,782.80
10	$ 386,179.68	$ 43,445.21	$ 429,624.90

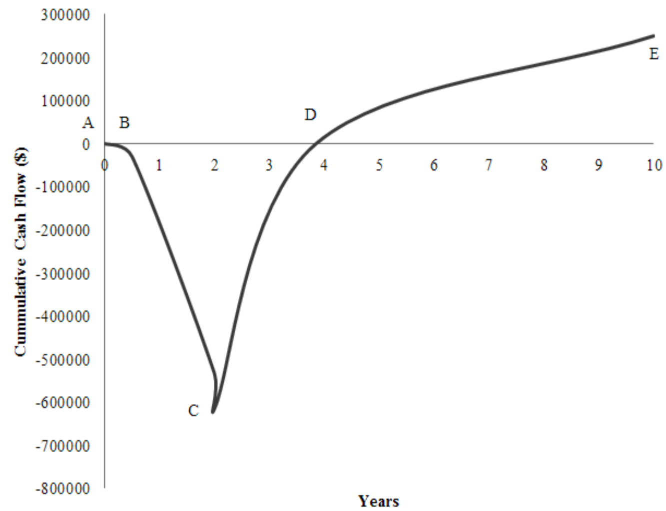

Fig. 2 Project cash flow diagram

Cash flow projections shown in Fig. 3 were prepared in order to evaluate the projects future cash requirements and to avoid crisis of liquidity. Cash flow projections over 10 years indicate project viability as revenue is higher than total operating costs. This is also indicated by the gap between revenue and operating costs which is the profit margin. Inflation rate of 6.4% influenced uniform yearly increments on the revenue and total operating costs.

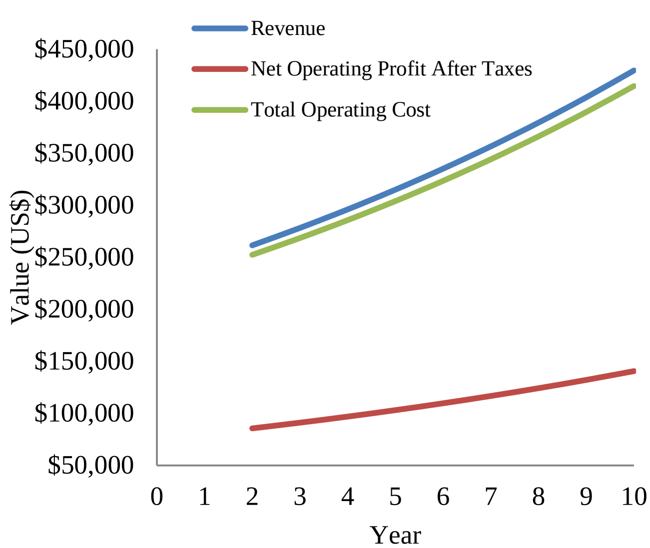

Fig. 3 Cash flow projections for 800kg/day treatment plant

IV. Conclusions

Thermo-chemical extraction of base oil from waste lubricating grease technology is one of the proven technologies that can be applied as an alternative method for the treatment and disposal of waste grease. 75w/w% oil can be recovered per batch of grease. The application was found to be economically feasible considering 800 kg waste grease per day production capacity. Recovery of oil from waste grease would be a favourable option compared to landfilling, incineration and other waste management techniques. The process offers both economic and environmental benefits.

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