South Asian Journal of Management Sciences
Vol. 6, No. 2, (Fall 2012) 50 – 60

Improving Reverse Logistics of Used Lubricant Oil for Re-Refining

Shahid Ahmed and Masood Subzwari*

ABSTRACT

Recycled used lubricant oils offers the benefits of recovering base oils prevents environment from harmful uses and protects the environment from disposal of used lubricant oils. It also promises to save billions of dollars of new base oil used in formulating new lubricant oils. It is argued that failure to ensure return of used lubricant oil and poor reverse logistics is the result of market failure, where the customer is not charged the true cost of using this valuable resource, which should include factors such as cost to the environment. This provides a possible economic rationale for government to intervene in the market to encourage return of used oil for recycling closer to the optimum level. The research found that charging an amount on the purchase of new lubricant, which would be adjusted on return of used lubricant oil, would ensure optimum return of lubricant oil. The amount should be high enough to discourage inappropriate users from buying the used oil. Alternatively, incentives such as free service or free replacement of oil filter could also be used. Findings suggest that the incentives such as free oil filter with oil replenishment or offering free car wash seems to be the most practical as it will also avoid the problems in handling and adjusting cash charged for ensuring used oil return.

Keywords: Reverse Logistics, Lubricant Oil, Refining, Oil Replenishment, Welfare Economics (Externalities)

JEL Classification: D62

Introduction

Lubricating oils are extensively used in industrial, business and transport sectors for lubricating machinery and engines. As oil becomes dirty and contaminated, it is withdrawn and used lube oil is replaced. The disposal of used lube oil is a serious environmental problem. As a part of lube oil supply chain, this oil needs to be returned to the manufacturers for recovering the principal ingredient, which is the base oil. It needs to be appreciated that lubricating oils are almost indestructible. When lube oil is replaced, it is just contaminated with external impurities and products of oil declension. These impurities can be removed by re-refining used oil. The re-refining process regenerates used lube oil into base oils, which are

* Corresponding author's email: **dr.smasood@iqra.edu.pk**
* The material presented by the author does not necessarily portray the view point of the editors and the management of the Iqra University, Karachi.

SAJMS 2012, Published by Iqra University
Defence View, Shaheed-e-Millat Road (Ext.), Karachi, Pakistan.

as good as pure base oil produced in petroleum refineries (U.S. Department of Energy, 2006). The re-refined base oil can be reused repeatedly after adding the usual additives.

An effective return system (reverse logistics) is crucial for the success of the re-refining industry. The industry and the Government of Pakistan are keen to promote re-refining of used oil. The Government issued many licenses to re-refiners and promised a quota of new base oil as an incentive to increase profitability of these units. Unfortunately, an ineffective collection and return system is the main obstacle to the success of this program. A number of these plants have either closed or have been forced to operate at much lower capacity. The lubricant industry is happy to be only concerned with the forward integration of the supply chain and they have nothing to do with the life cycle responsibilities of the lubricants. The lubricant manufacturers need to play their role in ensuring that the lube oil they produce does not create problems for the environment after it has served its purpose.

The collection and return of material is the reverse logistics part of the supply chain. The Council of Logistics Management, Rogers and Tibben-Lembke (1998, p. 2) specified reverse logistics as *"the process of planning, implementing, and controlling the efficient flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal"*

The technology for used oil re-refining is well established. In many countries, companies have established used oil re-refining capacity, which regenerate used oil to its base component, the base oil. The recovered base oil is identical to the base oil produced from lube bearing crude oil. Many small plants have been set-up to re-refine used oil in Pakistan. Unfortunately, many of these plants had to close or were forced to operate at under capacity due to an inadequate supply of used oil. In relevancy to Pakistan, this research investigated to improve reverse logistics and devise an efficient and effective collection mechanism that can return properly segregated used oil for re-refining to these plants.

Literature Review

The use of Lubricating oils is extensively seen in automobiles and other industries as well. Government of Pakistan report estimated that demand of automobile lubricants stood at 395,000 tons per year in 2008 (Hydrocarbon Development Institute, 2010). As lubricant is used, it gradually loses its efficacy due to contaminants from machine wear, other contaminants such as external impurities and combustion products, which makes it necessary to change the lubricant and withdraw the used oil. The used oil, however is only contaminated, the bulk of hydrocarbon in the lubricants (lube oil) remains unchanged and can be used repeatedly. If the reverse logistics can be effectively organized, the used oil can be regenerated to the main component of lubricant, the base oil. This recovered base oil then can be mixed with the additives and the new lubricant is then marketed again. The Government of Pakistan has issued licenses to setup plants with reclamation capacity of 140,000 tons per year (Hydrocarbon Development Institute, 2010). These plants are unable to find a certain supply of used oil and recently an attempt to import 10 million tones of used oil from international market made headlines in news media. Used oil is classified as hazardous material and under international laws (Basle Convention) its imports is strictly controlled.

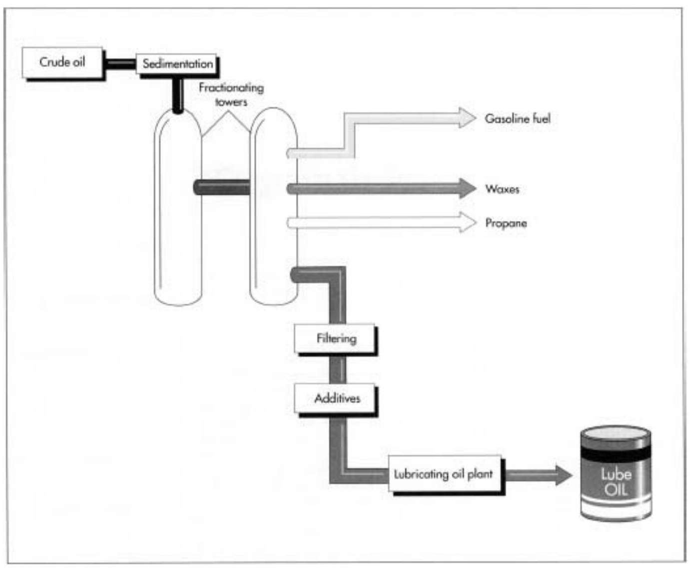
The quandary in organizing reverse logistics from dispersed customers is the main reason that this precious resource is used in unacceptable ways. The used oil is sometimes processed in back street shops using primitive techniques in an open pan with sulphuric acid to remove dirt and suspended matter, which is unethical. This acid bearing lube-oil is then re-sold by roadside vendors at very low prices. The lubricant processed in this manner damages the engines, causes pollution and also creates acid waste which is disposed off to cause pollution. Other unacceptable uses include burning used oil as fuel in brick kilns, using as coating to protect from rust and as wood preservative etc.

Lubricating Oils Manufacture

Crude oil is the most common source of mineral oils used in Lubricating oils (Lube Oils). The other type of lube oils are synthetic made from hydrocarbon-based polyglycols or ester oils (Whitlow, 2000). The synthetic oils are not part of this research.

Lube base oil stock (LOBS) can be obtained from lube bearing crude. It can also be recovered from used oil. The difference is that one barrel of LOBS requires 10 barrels of lube bearing crude, each barrel of LOBS recovered from used oil, saves the precious foreign exchange required for 10 barrels of lube bearing crude. Re-refining is a less energy consuming process too, compared to extraction from crude, it uses one third of the energy

Figure 1: A schematic diagram of lube manufacture



Source: Schematic Diagram of Lube Oil Manufacture (Whitlow, 2000).

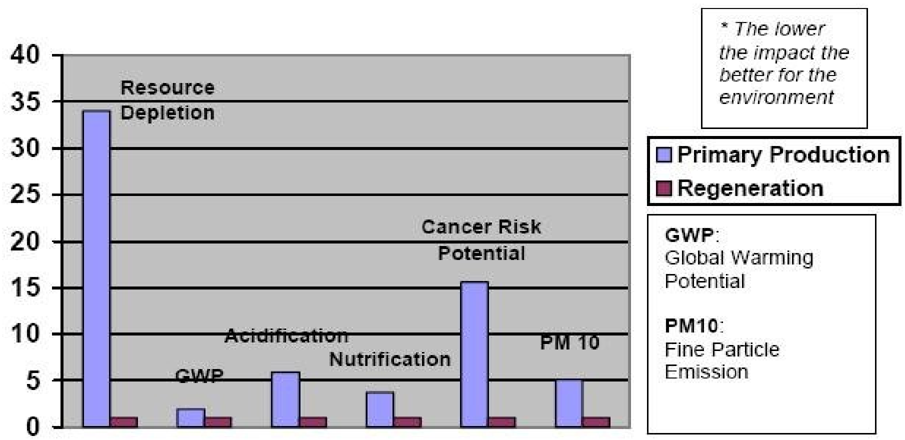
Lube Oil base stock (Base Stock) is processed into Lube Oil by adding a variety of additives such as metal sulphides, high molecular weight polymerics, nitrosomines and other proprietary additives to yield lubricating oils. These additives deteriorate with use in automobile engines and require replacement. The main component base oil can be regenerated by re-refining the used oil. Base oil in the international market is at present being sold at $1300/ tons (Dec 2010).

Inappropriate Uses of Used Oil

Used Oil contains heavy metals such as nickel, chromium, cadmium, copper, lead and zinc. It also contains polycyclic aromatic hydrocarbons (PAH) such as bezopyrenes, which are carcinogenic, and lubricant additives, which may also be harmful depending on their type and nature.

Mechanical disposal of used oil poses threats to both humans (lipid ganuloma in lungs, eczematous dermatitis, contact dermatitis, folliculitis, oil acne and melanosis) and ecology. In ecological terms, used oil is hazardous to biological cycles in the soil, embryo toxic to bird eggs, and dangerous to aquatic environment. One liter of oil can suffocate aquatic life under one hectare of water surface area.

Figure 2: Primary Production vs. Re-refining



Source: Primary Production vs. Re-refining (Groupement Européen de l'Industrie de la Régénération, 2009)

If used oil is put to inappropriate uses, new base oil stock is required for primary production to replace the used oil. A recent study carried out in Germany showed the environmental benefit of regenerating used oil (Groupement Européen de l'Industrie de la Régénération, 2009). The study compared the environmental impact of producing new lube oil against regeneration of used oil. It showed that the regeneration (re-refining) was preferable to primary production as it had a much lower impact on resource reduction, greenhouse effect, carcinogenic risk acidification, nitrification potential and fine particle emissions.

These uses are practical due to failure to collect significant quantity that can be refined in an economic and environmental friendly manner. The used oil disposal methods can be divided in two categories: unacceptable methods and acceptable methods.

Unacceptable Methods

1. As fuel in brick kilns
2. As fuel in cement kilns without pollution control
3. Mixed with bitumen for road surfacing
4. Dumping in pits
5. Acid-Clay re-refining (largely unacceptable but widely practiced and permitted in Pakistan

The unacceptability of burning of used oil in brick kiln/ cement kilns without pollution control requires no explanation. Availability of used oil at a price cheaper than other fuels and lack of strict environmental regulations is allowing this unacceptable and unethical practice to continue. Waste oil can possibly be burnt in systems designed to control pollution from incinerators. Use of waste/used oil in cement kilns is common in Europe but these kilns conform to pollution control standards. Waste oil (contaminated oil that cannot be re-refined) is best suited for this use as it allows the thermal value to be usefully recovered.

Mixing of used lubricating oil with bitumen is unacceptable. Bitumen is classified as a non-hazardous material while used oils are considered hazardous. The addition of unrefined used oil as a blending component to bitumen can pose potential health hazards due to contaminants in used oils (Gieseke, 2012).

Acceptable Methods for Used Lube Oil Processing

1. Vacuum distillation with clay treatment
2. Thin Film evaporation process
3. Vacuum distillation with hydro treating
4. Incineration with downstream pollution control

Among these methods, incineration with pollution control is suitable for lube oils that have become contaminated due to a variety of reasons such as mixed lubricants. This type of waste oil stock is unsuitable for re-refining and can be considered for controlled incineration. The other three methods require adequate availability of used oil and that is where an efficient collection system is crucial. The unacceptable methods of used oil applications can often work with small quantity of used oil, which is often collected locally on donkey carts or small pick-up vans from a few service stations. Therefore, in order to re-refine used oil on a larger and economic scale improved reverse logistic is an essential requirement.

Very often lube oil replacement is carried out at small service stations. As there is no monetary benefit in returning used oil, the consumer sees no benefit in ensuring that used oil reaches proper collection points. On the other hand, if the user had paid an extra amount which could be reimbursed when the used oil was returned to a collection station, the collection system would improve tremendously. It is therefore; clear that inability to collect used oil is the result of market failure. We use the term market imperfection or market failure to capture situations in which the incentives faced by individual decision makers are not aligned correctly with the social costs and benefits of their activities, so that unregulated individual actions bring about a socially inefficient outcome (Chander, Drèze, Lovell & Mintz, 2006). When the consumption of a product affects people other than the consumer or producer, we describe the impact as an externality (Samuelson, 1954). These externalities could be both positive and negative, for example construction of a motorway near my property could increase its value (a positive externality). Similarly, negative externalities, which are more common, adversely affect others. For example;

- A coal burning power plant producing acid rain affects the crops in surrounding area
- A plant emitting fine dust particles causes pollution and respiratory problems for nearby residents
- Smokers affect health of non-smokers
- Car users pollute the atmosphere, causing congestion and affecting others

In these cases, the producer and/or consumer should bear this cost as external cost. The basic theory of supply and demand and the resulting balance in supply and demand is well understood and shown in Figure 3 to Figure 4. The benefit the consumer receives from a product is considered in the terms of the price of a good or service. Figure 3 shows the demand curve that is the price the customers are willing to pay for that product or service at various prices, which is known as private benefit curve. Similarly, the supply curve (Figure 4) shows the quantity the producer is willing to supply at various good/service prices. This curve can be called a private cost curve. In a free market, equilibrium takes place when supply equals the demand and the private cost of acquiring a good or service is equal to the private benefit (Figure 5).

Figure 3: Private Benefit Curve: Demand vs. Price

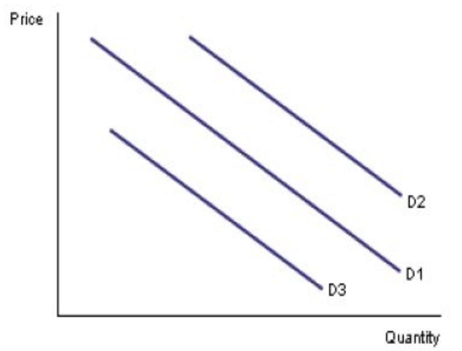
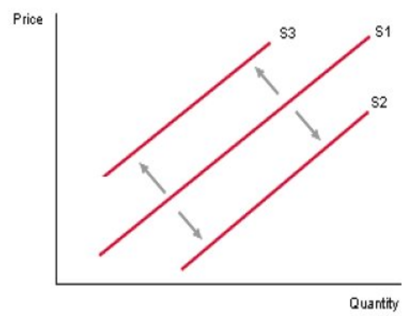


Figure 4: Private Cost Curve- Supply vs. Price



The supply and demand curve shown in Figure-5 only considers the private costs and benefits and not the cost of externalities. The production of lubricating oil involves both private and external costs. If the used oil is not returned to the producer the environmental cost are the external costs and these costs must be included in the supply and demand calculations. The full cost to the society includes both the private cost and external cost and is called Marginal Social Cost (MSC).

Figure-6 shows this cost superimposed over the Marginal Private Cost (MPC) curve. The shaded area is the marginal cost of the externalities. Externalities such as pollution are the spillover effect of market failure. It is difficult to put a value on these externalities as one cannot put a price on the degradation of environment, loss of valuable land and water resources. To counter this market failure, the economists seek to put a value on these spillover effects to force others to take measures to avert these externalities.

Figure 5: Demand under normal market forces

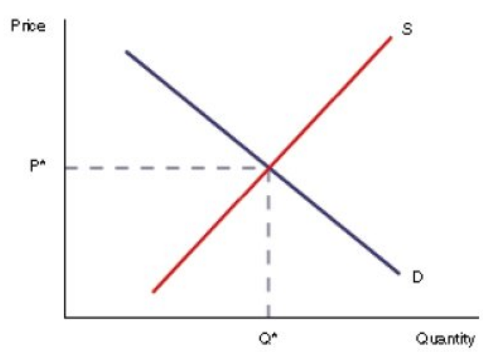
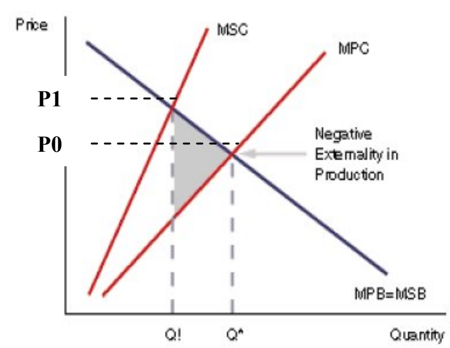


Figure 6: Demand Considering Social & Private Costs



The consumer and the producer should be asked to pay this cost. Returning the used oil to appropriate collection points/ service center will remove this externality and the consumer should be reimbursed the price paid to return the used lube oil. This is a very practical solution. The customer may be charged an additional amount per liter extra for new lubricating oil. This amount can be adjusted against future oil change when the used oil is returned.

Other similar measures can be included into the lube oil prices and incentives such as free-oil filter or free car service can be used to motivate the lube oil users to return the used oil.

In developed societies, the public is socially conscious and takes recycling seriously. The consumer can be trusted to return used items including used oil to designated places. Unfortunately this social consciousness is largely absent in our society and needs to be enhanced through mass education. These areas of promoting recycling and improving reverse logistics need to be explored in this study as an option to improve reverse logistics (Gieseke, 2012).

Organizing Reverse Logistics

In a very large number of cases reverse logistics is considered as essential for customer service as products are recovered due to expiry, malfunction or under warranty repair. For most companies reverse logistics is an additional cost as the returned material has to be disposed off. In a few cases salvage value can be extracted to meet some of the reverse logistics costs.

Reverse logistic of used oil promises to result in substantial net earnings and not costs. The re-refining plants at present cannot obtain sufficient used oil, which also explains the reason to try to import used oil through immoral means.

Used Oil is clearly available, 350,000 tonnes of new lube oil is entering into the market which means a similar quantity of used oil can be made available for re-refining. This is a challenge for the lube-oil supply chain; ensuring that reverse logistics can be organized to make the used oil available for re-refining. This objective of this research projected to explore the means of improving the reverse logistics.

Propositions

To remove the barriers to used oil collections by eliminating the negative externalities were investigated by the following propositions:

P1: Imposing a return charge on purchase of lube oil will help in ensuring return of used lube oil (RL).

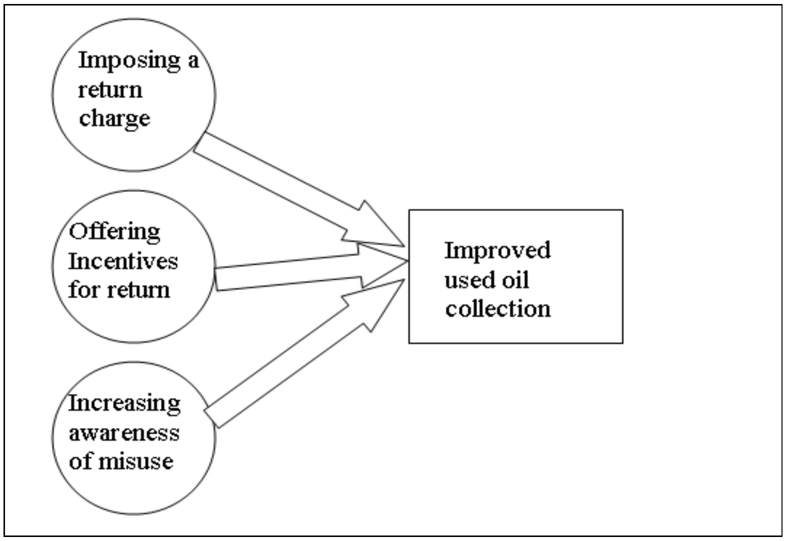
P2: Creating incentives such as discount based on every liter of oil returned or free oil change/free oil filter replacement will result in improved used oil collection (RL).

P3: Improving Reverse Logistics of Used Lubricating Oil for Re-Refining.

The research model for these propositions is depicted in Figure-7. It defines the dependent variable collection of used lube oil with the independent variables viz:

1. Charging varying amount adjustable in future purchases when used oil is returned
2. Incentives for returning used oil, free service, or oil filter etc.
3. An awareness campaign regarding misuse of lube oil

Figure 7: Research Model



Hypotheses

In order to test the three propositions, following hypotheses have been formulated:

H1: Charging Rs 20 refundable deposit has a positive impact on used oil recovery.
H2: Charging Rs 100 refundable deposit has a positive impact on used oil recovery.
H3: Charging Rs 150 refundable deposit has a positive impact on used oil recovery.
H4: Offering a free oil filter when returning lube oil has a positive impact on used oil recovery.
H5: Offering a free car wash when returning lube oil has a positive impact on used oil recovery.
H6: Promoting awareness regarding environmental impact of inappropriate disposal of used oil has a positive impact on used oil recovery.
H7: A concentrated campaign of the health risk of inappropriate disposal of used oil ensures that everyone returns used oil to designated service centers.

The hypotheses H1 to H3 are related to Proposition-1, hypotheses H4 and H5 are related to proposition-2 and the final two hypotheses H6 and H7 are testing Proposition-3. The above hypotheses were used to study the impact of independent variables such as lube oil pricing, offering incentives for return, environmental impact awareness on used oil collection efficiency.

Data description, sampling technique and research method

Quantitative methods have been used for this study to investigate variables distinctively and deriving to the final results and understanding for the identified propositions and hypotheses. The survey required a large sample, which is enough to yield the required degree of confidence level and margin of error. Fortunately, the sample size calculations showed that the sample size levels off as the sample size increases. For example, Raosoft sample size calculator showed this for a margin of error of 5% and a confidence level of 90% in Table 1 (Raosoft, 2004).

This sample size for this research is 385 restricted to the automobile industry of Pakistan in Karachi.

Table 1: Sample size as a function of population size

Population size	Sample size
10000	377
20000	377
200000	384
2,000,000	385

Instrument for Data Collection

In order to collect the data for analysis a simple questionnaire was designed on a 1-5 rating likert scale. As mentioned above the three propositions were put to the respondent in the form of seven questions. The respondent answered every question by simply selecting one response on a likert scale from 1. Strongly disagree to 5. Strongly Agree.

Statistical Analysis

The Likert scale survey can be analyzed with simple statistical technique one sample t-test. It was also essential to check the data's validity and reliability. A Cronbach Alpha value of 0.659 shows the reliability of analysis.

Descriptive Analysis

For statistical analysis, descriptive analysis was carried out first. The survey data was analyzed by using mode or the most frequent response. The frequency of responses showed that making a small return charge (Rs 5/liter) would not be sufficient incentive to return oil. While significant charge (presently assessed as Rs 25/liter to Rs 35/liter) will ensure that more than 90% of the consumer will return the used oil at designated outlets.

Incentives such as free oil filter change and free car wash offer are very popular with the respondents and almost 95-96% agreed that these incentives would make them return the used oil to the designated points.

The respondents agreeing that awareness campaign and awareness of health risk of misuse of lube oil was still positive but large number (13%) indicated that this would not be enough of motivation to return the used oil (Table 2).

Table 1: Frequency of Responses

	N	Agree	Indifferent	Disagree
H1: Charging Rs 20 refundable deposit will have a positive impact on used oil recovery.	385	11 (2.9%)	.370 (96.1%)	3 (1%)
H2: Charging Rs 100 refundable deposit will have a positive impact on used oil recovery.	384	379 (98.7%)	.5 (1.3%)	0
H3: Charging Rs 150 refundable deposit will have a positive impact on used oil recovery.	385	383 (99.4%)	2 (0.6%)	0
H4: Offering a free oil filter when returning lube oil will have a positive impact on used oil recovery.	385	379 (98.4%)	6 (1.6%)	0

	N	Agree	Indifferent	Disagree
H5: Offering a free car wash when returning lube oil will have a positive impact on used oil recovery.	385	382 (99.2%)	3 (0.8%)	0
H6: Promoting awareness regarding environmental impact of inappropriate disposal of used oil will have a positive impact on used oil recovery.	385	339 (88.1%)	39 (10.1%)	7 (1.8%)
H7: A concentrated campaign of the health risk of inappropriate disposal of used oil will ensure that everyone returns used oil to designated service centers	385	334 (86.7%)	45 (11.7%)	6 (1.6%)

Inferential Analysis

The statistical analysis showed that apart from the first hypothesis, which suggested Rs. 5/liter discount for returning the used oil, all other hypotheses were accepted.

Table 2: Hypotheses Assessment Summary

	Mean	Test Value	t-value	Sig.	Empirical Conclusion
H1: Charging Rs 20 refundable deposit will have a positive impact on used oil recovery.	3.02	4	-97.889	.000	Rejected
H2: Charging Rs 100 refundable deposit will have a positive impact on used oil recovery.	4.01	4	1.069	.286	Accepted
H3: Charging Rs 150 refundable deposit will have a positive impact on used oil recovery.	4.98	4	1.094E2	.000	Accepted
H4: Offering a free oil filter when returning lube oil will have a positive impact on used oil recovery.	4.86	4	43.247	.000	Accepted
H5: Offering a free car wash when returning lube oil will have a positive impact on used oil recovery.	4.90	4	54.624	.000	Accepted
H6: Promoting awareness regarding environmental impact of inappropriate disposal of used oil will have a positive impact on used oil recovery.	4.44	4	11.124	.000	Accepted
H7: A concentrated campaign of the health risk of inappropriate disposal of used oil will ensure that everyone returns used oil to designated service centers	4.47	4	11.590	.000	Accepted

Discussions and Conclusions

This research argued that failure to collect the used oil is the result of market failure where the user is not being charged for the damage that inappropriate use of this resource can cause to the environment. A comprehensive survey was carried out to assess the ways for improving used oil collection. The research concluded that given the right incentive/motivation, a very high percentage of the users would return used oil. This would require regulatory intervention. Major factors resulting through the analysis are as follows:

1. Charging an amount with every sale of lube oil that is adjusted towards future purchase would ensure that the user return the used oil at the designated service centers to claim the amount. The premium charged must be sufficient to be an incentive for the return. Our survey suggested that with present prices a charge of Rs 40 per liter would ensure 90-95% return.
2. Alternatively, a free car wash or free replacement oil filter also promises a very high percentage of used oil return.
3. The third option was to increase awareness of the consequences of misuse of used lube oil will only have a limited impact.

The research clearly showed that intervention by government and/or lube oil marketing companies are required to improve reverse logistics of used oil. In view of technical difficulties in collecting and refunding, the premium amount charged. It can be concluded that offering very attractive incentives such as free replacement filter or car wash to the consumers appear to be more practical. This incentive can be funded by increasing the lube oil prices to include the cost of providing the incentive.

References

Chander, P., Drèze, J., Lovell, C.K., & Mintz, J. (2006). *Public Goods, Environmental Externalities and Fiscal Competition.* U.S.: Springer .

Gieseke, W. (2012). The Recycling of Waste Oil. Hearst newspapers. Retrieved from http://homeguides.sfgate.com/recycling-waste-oil-79202.html

Groupement Européen de l'Industrie de la Régénération, GEIR (2009). *The Rerefining.* Retrieved from http://www.geir-rerefining.org/ .

Hydrocarbon Development Institute (2010). *Pakistan Energy Year Book.* Ministry of Petroleum and Natural Resources: Government of Pakistan

Raosoft. (2004). Sample Size Calculator. Retrieved from http://www.raosoft.com/samplesize.html

Rogers D., & Tibben-Lembke, R. (1998). Going Backwards: Reverse Logistics Trends and Practices. University of Nevada, Reno: Reverse Logistics Executive Council.

Samuelson, P. A. (1954). The Pure Theory of Public Expenditure. *Review of Economics and Statistics* (The MIT Press), 36 (4): 387–389.

U.S. Department of Energy (2006). Used Oil Re-refining Study to Address Energy Policy Act of 2005. U.S.: Office of Oil, Natural Gas and Fossil Energy.

Whitlow, C. (2000). How products are made: Lubricating Oils. Retrieved from http://www.madehow.com/Volume-1/Lubricating-Oil.html#ixzz17yTije5V