International Scholars Journals

Advanced Journal of Environmental Science and Technology ISSN 2756-3251, Vol. 16 (5), pp. 001-012, May, 2025. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Review

Feasibility Study of Small-Scale Used Engine Oil Recycling in Mechanic Villages: Potentials and Assessment

Michael A. Nwachukwu[1]*, Jude Alinnor[2], and Huan Feng[3]

[1]Department of Environmental Technology, Federal University of Tech Owerri, Nigeria.
[2]Department of Chemistry, Federal University of Technology Owerri, Nigeria.
[3]Department of Earth and Environmental Studies, Montclair State University NJ, USA.

Accepted 31 October, 2024

Mechanic village should be adapted in developing countries rather than the city-wide auto mechanic workshop practice. This is suggested because developing countries are yet to enforce environmentally friendly automobile workshops and mechanic practice. If all automobile repair works in different cities are confined to mechanic villages, collection, preservation, recycling and reuse of spent oil will become effective. The goal is to stop the habit of disposing spent automobile oil on the ground, which results in excessive trace metal pollution of topsoil and insecurity of food products in the affected areas. Beside environmental quality, business and employment opportunities will improve. Small-scale refining or reprocessing of used oil in mechanic villages is lucrative and recycling plants are affordable and available. Cost benefit analysis indicate strong environmental benefits and annual turnover in excess of $2,234,375.00.

Key words: Changed oil, reprocessing, re-refining, cost benefit analysis, auto repair, Nigeria.

INTRODUCTION

In some parts of Nigeria (Figure 1a and b), and many other countries, mechanic village (MV) is adopted against the city-wide spread of automobile workshops. A mechanic village represents several acres of land mapped out for automobile mechanics as against citywide automobile workshop practice (Figure 2a and b). It should be sited out of urban centers and kilometers away from urban residential areas as against the situation with many mechanic villages (Figure 2c). The hazard of environmental pollution through disposing used automobile oil on the ground in many developing countries is of great concern to public health and ecology. As automobile engine and transmission run simultaneously, metal particles wear and collect in the oil. This wear and tear of metal particles increases as the automobile gets older. The increasing demand of used or 'first end of life vehicles' (about 10 to 15 years old) by developing countries, and the matching supply by industrialized countries prevails. A paper presented by Ajayi and Dosunmu (2002) estimated an increase in the importation of used motor vehicles to Nigeria from less than 500 in 1988 to about 30,000 in 2000. The degree of used oils generation from vehicles in Nigeria could be estimated from the analysis of used crankcase oils based on the total vehicle registrations in the country.

Data from the Federal Road Safety Commission (FRSC) indicate the total number of vehicles registered in Nigeria between January 1999 and July 2004 as 5,828,900. Following this analysis, the estimated total number of registered vehicles by the end of 2011 is at over 7.0 million. Based on the 2004 figure, and assuming 70% of the vehicles are cars and the rest being trucks and buses, the estimated used crankcase oil was 150 mlpa. Industry-based used oil was estimated at 50 mlpa, leading to a total national used oil producing capacity of 200 mlpa (Bamiro and Osibanjo, 2004). The problem of used oil generation and the management is worldwide. In the United States alone, according to Nolan et al. (1990), an estimated 1.4 billion gallons of used oil is generated

*Corresponding author. E-mail: geoprobemd@gmail.com. Tel: +23408163308776.

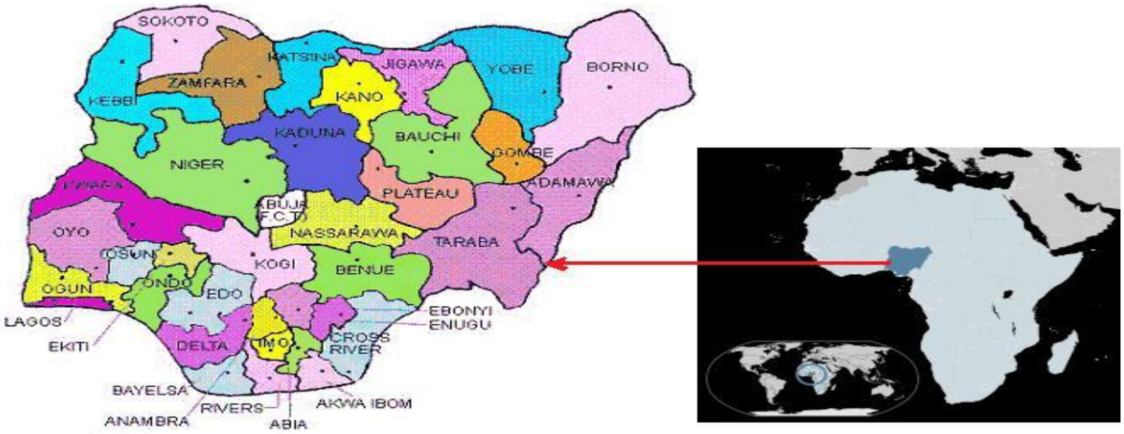

Figure 1. (a) Imo state Nigeria; 36 states and Abuja. (b) Continental and global location.

Figure 2. (a) Roadway to Orji mechanic village. (b) A section of Nekede mechanic village. (c) Satellite imagery showing location of Nekede and Orji mechanic villages.

each year, and this is to be managed by the plans specified by the Oil Pollution Act of 1990. As these old fuel guzzling vehicles are shipped to developing countries to avert recycling (Nwachukwu and Feng, 2011), they are subjected to a second cycle of life following continuous engine and body works; engine overhauling and parts replacement until they approach a 'final end of life' (another 10 to 15 years). During this second cycle of life, engine and transmission oil becomes more contaminated by fine metal particles due to increasing wear and tear Nwachukwu et al. 2010). In Nigeria for example, more than 80% of spent engine and transmission oil could be wrongly disposed on the ground by mechanics. According to Vest (1997-2000), used engine oil contains a number of additives, impurities, and residues resulting from the combustion process. Some of these are poisonous or carcinogenic like PCB or PAH (poly-aromatic hydrocarbons).

A city could have one or more mechanic villages where automobile owners must go for repairs and services to their motor vehicles. Disposing used oil on the ground by mechanics has the potential to pollute land, water, crops and ecosystem within and around mechanic villages. This amounts to public health hazards. It takes only one liter of oil to contaminate one million liters of water and a single automotive oil change produces 4 to 5 liters of used oil. Similarly, one gallon of oil is able to contaminate million gallons of drinking water and can form a thin layer of oil on the surface of the water which prevents oxygen from being dissolved in water. By this process, it hampers all kinds of aquatic life and the processes of photosynthesis as indicated in Rahman et al. (2008) and in Boughton and Horvath (2004). It is time to stop throwing changed oil on the ground by auto mechanics and consider small-scale waste oil recycling in mechanic villages. It is time to move all people involved in oil change such as motorcycle and electrical generator mechanics to mechanic villages. It is time also for cities in developing countries still using citywide poorly developed private auto workshops to consider environmentally friendly mechanic village practice (Nwachukwu et al., 2010).

Citywide auto workshop practice in poor developing countries causes citywide spill of used engine oil thus wider environmental pollution. In the citywide auto workshop practice, used oil collection is difficult and expensive. Vest (1997-2000) indicated that used engine oil is generated in small quantities at a great number of places, which makes collection of the oil for recycling difficult and expensive. According to him, many of the professional and in particular the majority of the private consumers of oil are not aware about the potential danger resulting from the improper disposal of waste oil. Recycled used oil can serve as industrial burner fuel, hydraulic oil, incorporated into other products or re-refined back into new lubricating oil. According to Odjegba and Atebe (2007), the carbohydrate content of plants grown in oil treated soils is significantly lower than that grown in plain soils. They also observed significant inhibitory effect on nitrate reductive activity in plants exposed to engine oil.

Legislative tools in support of used oil recycling in Nigeria

The legislative instruments developed by the Federal Ministry of Environment to halt environmental degradation arising from any pollution source including oil related activities are:

a) The National Policy on the Environment 1989 revised in 1999,
b) Nigeria's National Agenda 21 of 1999,
c) The National Effluent Limitations Regulations 5.1.8 of 1991,
d) Pollution abatement in industries and facilities generating waste regulation 5.1.9 of 1991,
e) Waste management regulations 5.1.15 of 1991,
f) Environmental impact assessment (EIA) Decree No of 1992, and
g) National guidelines and standards for environmental pollution control in Nigeria 1991.

RECYCLING METHODS

Many techniques are employed to treat waste oil. Some of these include acid/clay treatment, distillation processes, hydro treatment, solvent treatment, cracking, blending and compounding. To increase the purity of the treated oils, it is further refined using a combination of technologies such as decanting, settling and filtering. Recycling of waste oil is very important since in United States alone, it can yearly save the energy equivalent of 7 to 12 million barrels of crude oil, and provide employment.

Acid-clay process

Acid-clay process is one of the popular treatment methods for waste oil. In this process, the waste oil is treated with sulfuric acid. This acid reacts conversely with oxygen compounds and some sulfur- and nitrogen-based compounds to form sludge. Further refining is done in order to remove paraffinic and naphthenic hydrocarbons. Even after refining, there would be still some color and odor present in the oil which is later removed by treatment with activated clay. The problem with this method is that it produces a large volume of acid--sludge that is contaminated with petroleum. Due to these disadvantages, acid-clay process is now considered uneconomic since managing the residues incurs a huge cost. Nevertheless, Falah and Hussien (2011) demonstrated how this method could be used under different conditions and variables without bordering on the said disadvantages.

Dehydration method

Dehydration method is a process by which the impurities are removed through low temperature distillation. The oil thus refined is used as "cutter stock" for combining with heavy bunker oils. This process significantly reduces impurities in waste oil such as antifreeze, water and other solvents. The disadvantage is that this process does not reduce ash and such other residues, and this limits its use in other markets.

Hydro-treatment and cracking

Hydro treatment, cracking and high temperature distillation are some of the other methods employed to refine waste oil. This method is generally uneconomic, unsafe and is inconceivable to be used in a small scale. In hydro-treatment process, the waste oil undergoes a process that includes distillation and condensation. The resultant oil is hydro-treated for colour and odour correction. The oil is treated with nascent hydrogen in the presence of a catalyst.

Solvent treatment method

Solvent treatment method significantly reduces the impurities present in waste oil. The resultant refined oil is used as higher quality oil. In this process, the impurities are removed by a solvent-mixing process that does not include sulfuric acid. This solvent consists of butanol, methyl ethyl ketone and 2-propanol. The process produces a waste sludge removed as non-hazardous waste.

Recycling Options for used engine oil at mechanic villages

In this paper, we have defined two types of used oil

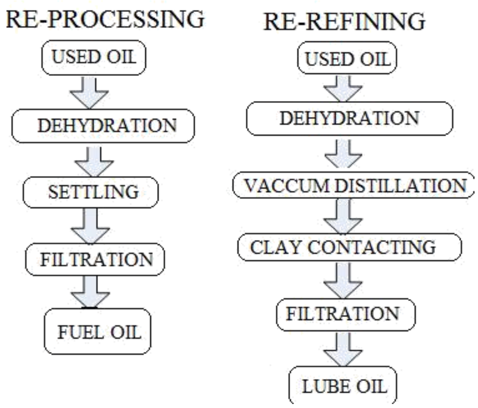

Figure 3. Reprocessing and re-refining processes after Bamiro and Osibanjo (2004).

recycling processes that may be suitable in mechanic villages:

a) Re-processing into fuel oil, and
b) Re-refining into lube oil.

Re-processing into fuel oil

A litre of used oil re-processed as fuel contains about 8,000 KJ of energy, which is enough energy to light a 100 W bulb for one day or to operate a 1000W electric heater for 2 h. Whereas 67 l of crude oil is needed to obtain a litre of motor oil, only 1.6 l of used oil are required to produce the same amount of motor oil (EPA, 1996). The unit processes involved in re-processing into fuel oil and re-refining into lube oil are compared in Figure 3. Waste oil used as a direct source of energy must undergo basic treatment to remove water and particulates before it is fit for use as fuel. This is to ensure that it does not clog burners, foul boiler tubes, or cause sediment build-up in customer tanks. As such, the process requires filtration and removal of coarse solids that can pose environmental hazard or operational problems. Treatment options include mainly physical processes like settling, centrifugation, filtration, or a combination of these operations. Unfortunately, these processes alone are not sufficient to remove all chemical contaminants in the oil, and inclusion of further treatment processes such as clay contacting and distillation would place fuel processors at a competitive disadvantage.

Utilising unprocessed waste oil as fuel for power generation, firing of boilers to generate process steam are associated with atmospheric pollution and increased hazards to human health. This is because of the relatively low temperature combustion of contaminants such as heavy metals and chlorides. However, higher levels of pre-treatment can remove water, sediments, heavy hydrocarbons, metals and additives (Bamiro and Osibanjo, 2004).

Re-refining

Recycling falls into two categories: regeneration and laundering. These basically differ only in the degree, and possibly the type of processing or cleaning required to recover reusable material from the waste product. Usually laundering applies to less heavily contaminated materials, which can be returned to original use with production of relatively little by-product. Regeneration applies to more heavily contaminated, or complex lubricating products which, when processed, produce a base stock and, usually, a greater proportion of by-products. The process typically involves, but is not limited to, pre-treatment by heat or filtration, followed by either vacuum distillation with hydrogen finishing or clay, or solvent extraction with clay and chemical treatment with hydro-heating. The vacuum distillation option followed by clay contacting offers a less polluting and more economic solution to the re-refining process, particularly for small scale plants with a capacity range between 10,000 and 30,000 tonnes (El-Fadel and Khoury, 2001).

A variety of proprietary technologies has been tried for regeneration with mixed success and various yields of base oil and by-products. They all seek to recover the base blending fluid, predominantly mineral hydrocarbon with growing amounts of synthetic petrochemical material, by separating it from additive chemicals and any breakdown products that arise during use. Invariably, there is a trade off between the quality of the recovered base oil and the sophistication of the technology. The capital outlay for re-refining process is becoming exorbitant due to the fact that lubricant requirements are becoming more severe, particularly in automotive applications as vehicles are subject to longer service intervals, smaller sumps and higher operating temperatures. The proportion of additives and synthetic components in lubricating oil is increasing, thus setting higher standards for recycled base oil.

Re-refining creates by-product streams that, in the case of the lighter components, may be used as fuel. The heavier residual stream containing additives and carbonaceous species may be used as a blending component in the bitumen industry for incorporation into construction work such as road surfacing. Thus, re-refining requires modern processes which are expensive to operate when all safety and environmental considerations are included into the overall operating system.

CASE EXAMPLES

Refining process of used engine oil in Cairo

Figure 4 represents a practical example of small scale Clay-process that can be visited in Cairo. The installed equipment allows refining 3.000 litres of used oil in one

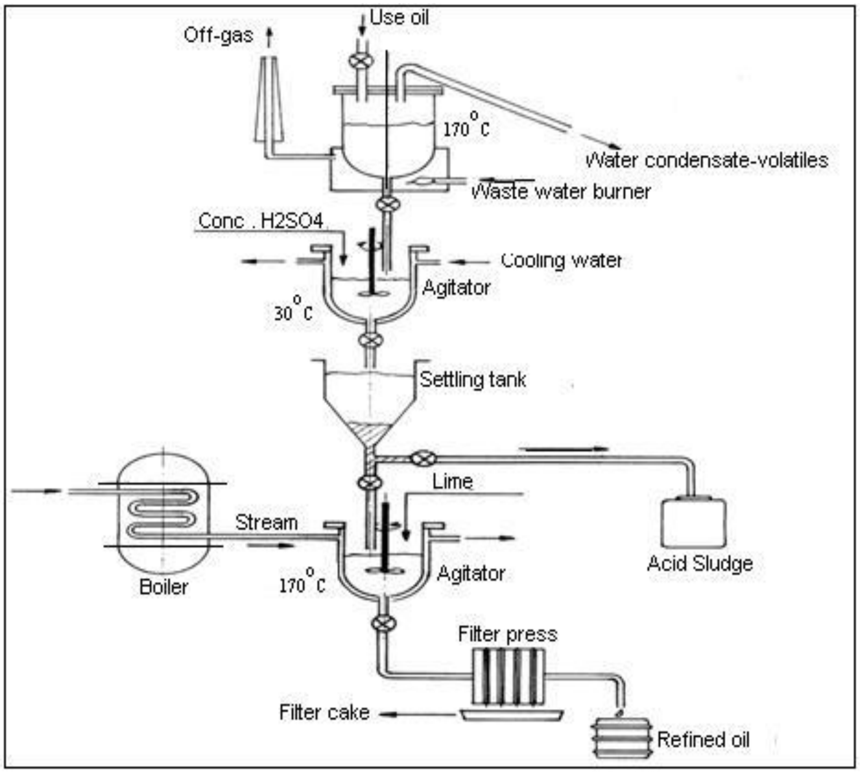

Figure 4. Small scale acid-clay-process in Cairo (Vest, 2000).

batch (Vent,2000). Only used engine oil is accepted for refining. The oil is collected from garages in the town or is delivered by individuals or intermediate waste oil collectors. It is stored at the recycling plant in old 200 l oil drums. To start the process the drums are emptied into a supply tank from where the oil is pumped into a heating vessel made of steel. The closed vessel is directly heated by a waste oil burner at the bottom. The oil is heated up to 170°C with an intermediate holding at 100°C to let the water content evaporate. Above 100°C other volatile matter are removed such as petrol or organic solvents which might have been mixed into the oil waste. Having reached the temperature of 170°C the oil is pumped into the first steel agitator. This open vessel is double walled to allow water to be pumped through as cooling agent. The oil is cooled down to approximately 30 to 40 °C. At that temperature, concentrated sulphuric acid is added at a quantity of 10% of the amount of oil. The mixture is stirred steadily for 3 to 4 h to let the acid react with the impurities forming sulphates.

The oil-acid mixture was afterwards pumped into cylindrical steel vessels with a conical shape at the lower end. It was kept there for one day to allow the insoluble sediments to settle in the bottom cone. Later the acid sludge was removed and filled into old oil drums for disposal. The remaining clear oil-acid mixture was subsequently pumped into a second open steel agitator. This agitator is double- walled as well, for heating purposes. The heating takes place indirectly using steam from a separate boiler. After filling the agitator with the oil-acid mixture (content 3000 litres), approximately 100 kg CaO or soda ash is added. Everything is heated up to 170°C while stirring. The whole process lasts for 2 to 4 h. The lime will react with the acid neutralizing the oil to pH 7 and forming gypsum. At the end of the lime treatment, the content of the agitator is passed though a filter press separating the solids (gypsum) from the oil. The clear oil is now pumped into storage vessels ready for distribution in small or big containers. The oil can be used for minor quality lubrication or cooling purposes, for example, for slowly moving parts, gearboxes or machines, during the machining of metals. One part of the refined oil is processed furtheron to grease. For that purpose the oil is mixed with Na- or Ca-stearate in a heated agitator and subsequently filled hot into containers for selling and distribution.

Past efforts to install used oil recycling plants in Nigeria

In 1996, Lube Oils Limited with the assistance of UNIDO assessed the techno-economic importance of refining used lubricating oil in Nigeria. Triple E Associates carried out a feasibility study that supported establishment of used oil recycling plant. Since after the study, no used oil recycling plant is installed in any part of the country. According to Bamiro and Osibanjo (2004), two important reasons are responsible for this:

1. The project increased in cost from an initial projection of ₦100 million to over ₦1.0 billion. This is because the project was based on a complex Italian Process design.
2. Problem of getting sufficient quantity and quality of used oils to make the project economically viable was envisaged. This was obvious because Triple E Associate failed to investigate used oil production potentials of mechanic villages. Lube Oils Limited still very much interested in used oil recycling process, has decided to invest in the local development of appropriate process technology. Towards this end, it has entered into research agreement with the Department of Chemical Engineering University of Lagos to develop the technology in stages: first, a plant to process used oil to fuel oil; then, to diesel oil in the second stage; and finally, a re-refining plant to produce base oils. The Federal Ministry of Environment on their own has invited bids for the fabrication of a used oil refining plant based on the acid/clay process technology. The contract for the fabrication was since been awarded to a fabricator. It is hoped that the Ministry will be in position to provide the very much needed research and technological backup for such project whose requirements for success transcend mere fabrication. This is particularly important since the process technology is not yet in the public domain, and researches are still going on even in developed economies.

A recent plan by the River state government to establish used oil processing plant is welcome. This singular project with elaborate design contracted to an American firm may become the first used oil recycling plant in Nigeria if finally put in place. Despite the huge cost of this project, a greater concern is the running cost and sustainability of this expensive project. It is not likely that this plant can take care of used engine oil from industries, automobiles and generators from Rivers state alone since the logistics for collection is not in existence or planned. In the absence of a full mechanic village system as against citywide automobile workshop system in River state, changed oil collection will be difficult. Incidentally, such elaborate used oil recycling facility may not be sustainable, and not likely to solve the problem of used oil management in the cities without integrating the concept of mechanic villages.

ECONOMICS OF THE STUDY

On the average, a mechanic village may have 450 registered mechanics exclude apprentices specializing in different makes of motor vehicles. Whereas a mechanic may have two or more oil change per day, an average of two oil change per day gives about 900 gallons of oil daily per mechanic village. This is roughly 900 x 320 = 288000 gallons per year or 1,152,000 l. Udebuani et al. (2010) estimated 1.4 million liters of spent oil as produced yearly in the Nekede MV. The Nekede MV is large with estimated 600 mechanics. The volume of used oil produced from each mechanic village is enough to sustain small scale recycling business which is presently unavailable.

A recent study (Nwachukwu et al., 2010) of Okigwe, Orji and Nekede MVs in the Imo state of Nigeria shows the first 100 cm topsoil within and around the MVs to have moderate to excessive heavy metal pollution. Metal concentrations (mgkg^{-1}) above the background levels in the topmost 100 cm of soil profile ranges as follows:748 to 70,606 for iron (Fe); 99 to 1090 for lead (Pb); 186 to 600 for manganese (Mn); 102 to 1001 for copper (Cu); 8 to 23 for cadmium (Cd); 4 to 27 for chromium (Cr); and 3 to 10 for nickel (Ni). The order of abundance is: Fe >Pb>Mn> Cu > Cd > Cr > Ni, with Okigwe>Nekede> Orji based on pollution factor (Pf). Pb, Mn, Cu, Zn distribution largely exceeds local threshold and crustal values and beyond 200 m from a mechanic village, in the direction of drainage. The result is medium to excessive soil pollution, surface and groundwater pollution, and constituting major threat to public health and safety. The above pollutants are predominantly from changed oil disposed on the ground as a habit by mechanics. This habit can be stopped if small-scale recycling business is introduced in mechanic villages with incentives to the mechanics. Adebayo et al. (2004) presented a comparative analysis of Nigeria used and virgin engine oils (Table 1).

There is no plan to collect; safely dispose, store or recycle spent automobile oil yet in Nigeria and in many African countries. Nwachukwu et al. (2010) recommended extended producer responsibility (EPR) in management of spent oil. An arrangement whereby the oil producers represented by the major marketers or gas stations may be obliged on routine bases to go to mechanic villages and collect spent oil for recycling or proper disposal. The government on their part may be obliged to make available storage containers to mechanics in all mechanic villages. The mechanics on the other hand need some education on the environmental health, their occupational health and safety as consequences of their poor management of changed oil.

A 2004 report by the Basel Convention Regional Centres in Africa to put in place environmentally sound management practices for used oil has made no impact towards waste oil recycling in Nigeria. In the analysis of used oil generation, the Basel convention group failed to investigate mechanic villages, whereas mechanic villages represent the major producers of waste oil in Nigeria. The group presented statistics of oil generation in some

Table 1. A comparative analysis of used and virgin engine oils: Virgin oil unleaded.

S/N	Test parameter	Used oil (a)	Used oil (b)	Virgin oil
1	Specific gravity (15.6°)	0.901	0.8952	0.8782
2	API gravity (15.6°)	25.55	26.57	29.63
3	Copper (mgl^{-1})	1.09	1.18	1.01
4	Chromium (mgl^{-1}	0.06	0.07	0.04
5	Nitrate (mgl^{-1}	10	4	4
6	Calcium (mgl^{-1})	80.6	80.6	28.75
7	Iron (mgl^{-1})	81.8	72.7	14.1
8	Barium (mgl^{-1})	4	4	2
9	Magnesium (mgl^{-1})	0	0	0
10	Phosphorus (mgl^{-1})	0.36	0.58	0.34

Source: Ogbonna and Ovuru (2000).

isolated mechanic workshops, a total of which is far less than that generated in one mechanic village. To fill the gap between the refining and/or re-use of oil waste in big industrial plants on one side and an indiscriminate disposal of waste oil on the ground in mechanic villages, there is need for small-scale processing plants. This will create better job opportunity, new products and minimise the amount of waste.

The primary goal of this paper was to introduce the business of small-scale waste engine oil recycling in Nigeria mechanic villages. This is because a small scale private or government owned used engine oil recycling plants in mechanic villages would be economical and lucrative. It will be more sustainable than a complex large scale recycling plant isolated in one corner of the country. Now there is no used oil recycling plant in Nigeria, and the business of used oil recycling is yet unknown. Several reasons may account for this:

a) Poor knowledge of resources conservation management and sustainable development, because Nigeria produce oil and do not care about oil and gas wastes.
b) Poor knowledge of recycling and negative attitude to waste; because recycling as a method of waste management is yet to be properly integrated into Nigeria waste management culture.
c) Cost and lack of machineries: a function of poor economy, weak currency or unstable high exchange rate.
d) Over dependence on government with poor private sector orientation; the need for a revolutionary industrial orientation that will stress private sector cottage industries.
e) Investors lack motivation and incentives from government and financial institutions; the need for soft loans, micro finance banking, and minimal import duties for industrial machines to private sector investors.

Economic importance of used oil

Used oil has many local applications (Table 3) that could account for about 20% of it produced in most Nigeria cities. Of this 20%, about 5% is further spilled on the ground during the application (Table 3). The other 80% undoubtedly is disposed on the ground as waste, thus causing serious environmental concern. In this paper, environmental analysis of the local uses of used engine oil and chemical composition of virgin and used oils are presented. The parity in chemical composition is due to contamination from wear and tear of engine and transmission. Comparative chemical analysis of virgin oil with lead (Pb) and without Pb, and used oil with Pb and without Pb is reviewed. Existing technology for small scale recycling of used automobile oil adaptable in mechanic villages is investigated. Availability of land, collection of waste oil, labor and financing is discussed. Education of mechanics and information tool that will enable them to comprehend the ramifications of wrong disposal of changed oil is another important issue addressed.

In Nigeria as in many developing countries, used engine oil is often applied as fuel in different small-scale applications. Apart from its use in foundries, traditional brick and lime kilns, the oil is also used in bakery. It is often blended with tar oil, or rubber pieces from used tyres in asphalt production. In some cases, waste oil can be mixed in small quantities with diesel to enhance running efficiency and fuel conservation in diesel engines. Another application of waste engine oil is in production of grease. To produce grease, waste oil is added to a local soap prepared with palm kernel oil (PKO) when the oil soap is still warm and soft. This is made in a composition of 20% soap to 80% waste oil. The mixture is vigorously stirred for a while until the grease is formed. The oil determines the viscosity of the final grease. The low quality grease however is sufficient for many minor applications.

Apart from the use of waste oil as fuel or for producing grease, some "traditional" applications exist; old engine oil is used as a timber-protecting agent. Fence posts, for example, are soaked in used oil to make them resistant against termite attack. Used engine oil is applied on cows as protective medicine against ticks or on floor, to control dust and tick. Waste oil is used for heating or for minor energy production as a cheap fuel. As a routine, police officers usually burn waste oil at check points in the night for illumination and to indicate their presence. Depending on the composition and the impurities in the used oil the off-gas produced by this operation may be very dirty and hazardous. Therefore, the current practices are not environmentally friendly or climate compatible. These practices can be hazardous to people living nearby. If the off-gas is properly cleaned, waste oil can be used for heating and energy production. In industrialized countries, there are many companies offering special

Table 2. Virgin oil leaded.

S/N	Test parameter	Virgin oil	Used oil
1	Specific gravity (60°F/60°F)	0.899	0.903
2	Viscosity (Cst) (100°F)	171.3	101.48
3	Viscosity (Cst) 210°F	16.9	12.02
4	Dynamic Viscosity (Cp) (100°F)	152.87	90.97
5	Dynamic Viscosity (Cp) (210°F)	15.08	10.77
6	% Ash	0.2	0.75
7	% Sulphated ash	0.35	0.85
8	Flash point (°C)	250	146
9	API Gravity (15.6°)	25.95	25.25
10	Nitration products	3	1
11	Nitro-compounds	3	0
12	% Water	5	14
13	% Oxidation products	9	16
14	% Glycol	0	0
15	Fe (ppm)	1.04	98.95
16	Cu (ppm)	0.31	20.09
17	Pb (ppm)	5.70	604.9
18	Cr (ppm)	0.20	1.27
19	Ba (ppm)	604.9	608.04
20	Zn (ppm)	1630.2	1724.19
21	Ca (ppm)	1200	1300.21

Adebayo et al. (2004).

designed waste oil burners. Incinerator for waste oil which is attached with off-gas heat exchanger supply steam to small steam turbines or steam motors for electrical energy generation.

The principal objective of any waste management plan is to ensure safe, efficient and economical collection, transport, treatment and disposal of wastes, as well as satisfactory operation for current and foreseeable future scenarios, (Nema and Modak, 1990). Recycling of used oil entails acquisition and processing to regain useful material. In recycling process, a number of stages are possible depending on original source of the used oil, the level of contamination, and the sophistication of technology deployed. Ogbonna and Ovuru (2000) (Table 1) and Adebayo et al. (2004) (Table 2) carried out chemical tests on samples of virgin oils and used oils in the Nigerian market. The test results showed remarkable increase in calcium, lead, copper and iron concentrates in the used oil samples compared with the result for the virgin oil. Of course, qualities of contaminants in used oils depend on several factors including type of original additives to the virgin oil, condition of engine where oil was used, and collection and storage practices.

Cost-benefit analysis of small-scale changed oil recycling in a mechanic village

Imo state (Figure 1a), is about the 34th position in land mass, but about the 13th position in human population in Nigeria. As a result, there is a high population to automobile traffic density that makes the city of Owerri environmentally congested and polluted. There is limited arable land all of which justifies environmental alert over disposal of spent engine oil on the ground in mechanic villages. To rescue this situation, small-scale used oil recycling business in all mechanic villages is recommended. The business is lucrative, stand supported by government and by financial institutions.

Results of investigation showed that an average of about 1.3 million liters of spent engine oil is produced annually in a mechanic village. About 90% of the mechanics disposed spent engine oil on the ground within their working environment, while 10% was used for other purposes, such as pest control, sharpening of blades and reuse in heavy trucks among others. Not less than 90% of mechanics are ignorant of environmental impacts of inappropriate spent engine oil disposal. The environmental impacts; soil, water, ecological, food products, and public health hazards can hardly be quantified. Based on the comparative analysis of used and virgin engine oils (Tables 1 and 2), mechanic villages are now brown fields. Soil within and around mechanic villages will require special budgetary allocation for remediation. Such remediation program is within reach, or priority list of neither the state government nor the local government owners of mechanic villages in Nigeria.

Table 3. Environmental impact assessment of local uses of changed engine oil.

Local uses of used oil	Application	Environmental effect
Road construction	On the ground	Soil pollution
Rust prevention	On a metal device	Stains on contact
Old engines emergency lubricant	Automobiles, generators	Air pollution, waste (as end of life vehicles)
Wood preservation	Timber; roofing, fencing	Land pollution
Mixed with grease for gear oil	Gear box lubricant	Spills; Soil pollution
Production of grease	Automobile lubricant	Stain on contact
Burning, Boilers, furnaces	Burners, bakery, incinerators	Off-gas, air pollution
For pest, weed, and dust control	Garden, workshops	Soil pollution
Hydraulic oil	Props, Lifts, Jacks	Spills
Ball joint oil and nuts loosing oil	Ball and socket joints, nuts	Stains on contact
Block and Balustrade mold lubricant	Block, bricks, balustrade molds	Spills
Medication	Wound and cuts	Additional Health effect
Dust and tick control	Land, floor	Land pollution, Stains

Table 4. Advantages and disadvantages of the two applicable recycling options.

Option	Advantage	Disadvantage
Re-refining into lube oil Or Re-processing into fuel oil	Mechanic village provides well-developed used-oil collection system. Provide environmentally sound used oil management. Create local jobs. Reduce the amount of imported fuel and base oils for local uses. Products can be exported to other West –African countries. Used oil from millions of private electric generating plants and industries will supplement daily production of used oil in mechanic villages, thereby increasing turnover. Re-processing will appreciate now without fuel subsidy.	Standard of products may be poor. Value and marketability of products may be low. End-waste residues disposal may create problem.

Considering environmental impact assessment of local usage of changed engine oil (Table 3), the environmental effects still indicate wider pollution, and economic loss.

Further analysis (Table 4), based on the two recycling options that may be applicable justifies small-scale used oil recycling in mechanic villages as economical and with great advantages.

If 1 l of used engine oil is reprocessed to obtain fuel capable of 8000 KJ of energy. Then reprocessing used engine oil generated from Nekede mechanic village alone will yield 8000 x 1300000 = 10,400,000,000 KJ of energy, based on the average of values obtained by Nwachukwu et al. (2010) and Udebuani et al. (2010); whereas 8000 KJ of energy could light a 100 W bulb for one day, used engine oil from Nekede mechanic village in one year will support:

——— = 3562 of 100 W bulbs for 1 year

3562 of 100 W bulb can sustain streetlights in Owerri metropolis for one year.

If on the other hand, the choice is to re-refine the used engine oil from Nekede mechanic village alone into lube oil, and 1.6 l of used oil gives 1 lilter of motor oil, then;

——— = 812500 litres of re-refined lube oil

Oil treatment may be added if need be, to improve its quality and market. 1 l of lube oil without oil treatment when sealed, cost 400 naira or $2.5. Recycled lube oil can sell at 400 naira when containing oil treatment, and 300 naira without oil treatment. If production is with 10% of oil treatment, then 812500 l will require 81250 l of treatment oil.

Total volume of recycled lube oil = 812500 + 81250 = 893750 l
893750 x 400 = 357,500,000 naira about
$2,234,375 (USD)

By this analysis, a small-scale used engine oil recycling business in a mechanic village detailed to re-refining to

Figure 5. Chongqing Tongrui used oil recycling plants.

lubricating oil can make annual turnover in excess of $2,234,375.00 at minimum cost. Besides, the environmental benefits of this recycling largely justify the efforts and the investments.

Availability of small-scale used engine oil recycling plants

1) There are a number of small-scale refining processes for used oil in the market. Small- scale used engine oil recycling plant is available at low cost with good technical characteristics as shown in Figure 5.
2) No secondary pollution during the treatment process: No waste gas or water released into the atmosphere, and the distillation residue can be used for fuel.
3) Low treatment cost and energy use 105 kcal/ton of base oil distillation heat, and power consumption: 15 kwh/Ton base oil.

Example of companies supplying small-scale used oil refining plants

Chongqing Zhongneng Oil Purifier Manufactures small-scale Engine oil recycling system Chongqing Tongrui Filtration Equipment Manufacturing Co. Ltd for used oil regeneration machines.

Eschborn, Germany Phone: +49 (0)6196 / 79-3093, Fax: +49 (0)6196 / 79-7352, Email: gate-id@gtz.de, Internet: http://www.gtz.de/gate/gateid.afp.
AXXON B.V. Postbus 256 6800 Arnheim The Netherlands Phone: ++31/26/4455723 Fax: ++31/26/4427163.

Envirosystems Inc. 11 Brown Avenue, Darmouth Nova Scotia, Canada B3B 1XB phone: ++902/481/8008 fax: ++902/481/8019 Mike@enviro.systems.com.

CONCLUSION

The environmental hazards associated with disposal of spent oil on the ground in different parts of Nigeria and in other African countries are enormous. The problem is more severe in Nigeria where private sector investors have neglected the used oil recycling business because of the availability of oil and oil products in the country. Investors are one directional on the issue of used oil recycling. They are after the financial benefits and the establishment of a large-scale venture. As a result there is not yet a single used automobile oil recycling plant in the country. This paper informs that small-scale used oil recycling is lucrative, and can be economically housed in mechanic villages. The paper on the other hand encourages the establishment of mechanic villages near urban areas where all mechanics concerned with automobile works and oil change may operate. This will facilitate private small-scale used oil collection and recycling in the cities. Waiting indefinitely for multi-million dollar recycling plants to be established by government is not good enough for industrialization and sustainable development. Beside the substantial economic benefits, small-scale used oil recycling in mechanic villages will provide employment, help in poverty alleviation, and improve environmental quality. Other business sharing benefits such as: availability of operational space, used oil, cheap labour, bank financing and cheap overhead cost exists.

There are inconveniences in travelling far distances to obtain the service of a mechanic due to preferred location of mechanic villages off urban centre and residential areas. That notwithstanding, the concept of mechanic village is the surest way to enable collection and recycling of spent engine oil in developing countries. The quantity of used oil available for re-processing/re-refining may be reduced by the present alternative uses particularly as fuel, in industry. Used oil has commercial value and will therefore attract cost as input to any planned re-processing or re-refining plant. This is because whether a used oil producer sells or not will be dictated by the cost-benefit analysis of selling instead of its usage as fuel in-house, for example. The rather high cost of energy in the country may tilt the decision in favour of internal use. It could be as fuel supplement for companies with energy-intensive operations. Cost of used oil in isolated service stations may vary from 5 naira to 20 naira per litre in cities. In mechanic villages, it is largely disposed on the ground and can be obtained free or at minor cost. However, the business of used oil recycling in mechanic villages may impose cost on used oil as incentive to making mechanics responsive to the storage and supply. Obviously small scale recycling processes might not be able to achieve an oil product of high quality. However, quality of the recycled oil can be upgraded by adding standard oil treatment.

RECOMMENDATIONS

Government regulation may compel changed oil from electric generators in homes, offices and in business premises to supply such oil for recycling free or a fee per gallon. An important requirement is to enact a new legislation regulating the establishment of automobile mechanic villages across the country. A section of the mechanic village may be reserved for maintenance and services of electric generators. A primary goal of this project is to concentrate all activities involving oil change to mechanic villages. In absence of used oil recycling facility in a mechanic village, the new legislation will empower extended producer responsibility (EPR) for routine collection of used engine oils by the nation's major oil marketers. By EPR requirements, major oil marketers or their gas stations representing the producers shall be mandated by law to collect changed oil from mechanic villages on routine bases for recycling or proper disposal. Government owners of mechanic villages shall provide adequate storage facilities for changed oil in mechanic villages. The law to stop disposing changed oil on the ground and to comply with the order of storage on the other hand shall be enforced with appropriate penalty.

Re-processing of used oil to fuel oil will be a most attractive management option in view of the high cost of energy. Today, private electric generating plants can be found in almost every household, office, and even the smallest business places and in Nigeria. This development produces large amount of used oil to add to the quantity in mechanic villages. Recycling operators in mechanic villages will make extra efforts to reach understanding with used oil producers outside mechanic villages to increase supply in line with their demands.

Small-scale oil recycling in mechanic villages is lucrative. Enforcement of appropriate laws by government agencies and the union of mechanics will facilitate collection and preservation of used automobile oil for recycling. Recycling operators and government may sponsor environmental workshops and training programs for mechanics.

ACKNOWLEDGEMENT

We are particularly grateful to members of Federal University of Technology- Environment and Sustainability Study Group for their research information during meetings. Special thanks go to Mrs. Ijeoma Nwachukwu for assisting in the word processing.

REFERENCES

Adebayo AO, Osibanjo O, Olonisakin A (2004). Physico-chemical treatments and analyses of crankcase oil. Ultra Sci. 16(1):19-24.

Ajayi AB, Dosunmu OO (2002). Environmental hazards of importing used vehicles into Nigeria, in Proceedings of international symposium on environmental pollution control and waste management Tunis EPCOWM; pp. 521-532.

Bamiro AO, Osibanjo O (2004). Pilot study of used oils in Nigeria; Report of Study sponsored by the Secretariat of the Basel Convention 2004.

Boughton B, Horvath A (2004. Environmental Assessment of Waste oil Management Methods. Environ. Sci. Technol. 38(2):353-358.

El-Fadel M, Khoury R (2001). "Strategies for vehicle waste-oil management: a case study". Resour. Conserv. Recycling 33:75-91.

EPA (1996). Managing Used Oil: Advice for Small Businesses. Report, 530EPA-F-96-004.

Falah BH, Hussien A-W (2011). Regeneration of base-oil from waste-oil under different conditions and variables. Afr. J. Biotechnol. 10(7):1150-1153.

Nema AK, Modak PM (1990). A strategic design approach for optimization of regional hazardous waste management system Science Direct; Waste Manag. Res. doi: 10.1177/0734242X9801600303

Nolan JJ, Harris C, Cavanaugh PO (1990). Used oil: disposal options, management practice and potential liability: 23(1):130.

Nwachukwu MA, Huan F (2011). A critical review of the management options for end of life vehicles (ELVs) and waste electrical/electronic equipment (WEEE) in the 21st century; Glob. J. Environ. Sci. Technol. 1:5.

Nwachukwu MA, Huan F, Achilike K (2010). Integrated study for automobile wastes management and environmentally friendly mechanic villages in Imo River basin Nigeria. Afr. J. Environ. Sci. Technol. 4(4).

Odjegba VJ, Atebe JO (2007). The effect of used engine oil on carbohydrate, mineral content and nitrate reductase activity of leafy vegetable (*Amaranthus hybridus* L). J. Appl. Sci. Environ. Manag. 11(2):191-196.

Ogbonna J, Ovuru SE (2000). "Pollution Control with a focus on recycling of used luebe-oil", Nigerian Society of Chemical Engineers' Proceedings, pp. 150-159.

Rahman MM, Siddiquee TA, Samdani S (2008). Effect of Operating Variables on Regenerating of Base-oil from Waste oil by Conventional Acid-Clay Method. Chem. Eng. Res. Bull. 12:24-27.

Udebuani AC, Okoli PC, Okoli I, Nwigwe HC, Ozoh PTE (2010). Assessments of the volume and disposal methods of spent engine oil generated in Nekede mechanic village Owerri, Nigeria Report Opinion, 3(2). http://www.sciencepub.net/report

Vest IH (1997). Reuse and Refining of Waste Engine Oil Technical Information W17e.

Vest IH (2000). Reuse and Refining of Waste Engine Oil, A Technical Information W17e. at www. gate international.org/documents/techbriefs/webdocs/pdfs/w17e_ 2000.pdf Extracted 12/03/2012