Enhancing Cleaner Production Practices in Downstream Petroleum Lubricants Industry

Ignatio Madanhire, and Charles Mbohwa

***Abstract*—**This work highlights Cleaner Production (CP) opportunities available in Downstream Petroleum Lubricants Industry with view to reduce negative environmental impacts of lubricants throughout the value chain. Effort was made to investigate existing cleaner production practices by manufacturers and users. Options were generated to improve on the current practices. Base oil substitution, minimizing oil losses during and after manufacturing, raw material and energy consumption reduction, and environmentally friendly used oil disposal were considered for effectiveness.

***Keywords*——** blending, lubricants, cleaner production, environment, waste.

I. Introduction

THE documented detrimental effect of petro-chemicals on flora and fauna, demands that close monitoring is done for the entire process of manufacturing, application and disposal to safeguard the environment [2]. Hence need to investigate this area and recommend possible areas of improvement to comply with emerging and demanding regulatory requirements.

Although considerable research has been devoted to impact of petroleum fuels, less attention has been paid to pollution resulting from lubricants on disposal [8].

II. Background

Currently, waste oil disposal involves taking and dumping garbage at the major landfills dump sites located around the country resulting in soil degradation and water contamination. It is in this regard that other than concentrating on the final disposal of used oil, a lot can be done to reduce lubricants waste by looking at the product life cycle from manufacture, distribution, application and disposal [9].

III. Environmental Impact Of Lubricants

A lubricant (sometimes referred to as "lube") is a liquid substance introduced between two moving metal surfaces to reduce the friction between them, improving efficiency and reducing wear. The single largest application for lubricants is protecting the internal combustion engines in vehicles as motor oil [1]. Typically lubricants contain 90% base oil (or mineral oils) and less than 10% additives. Also synthetic liquids such as hydrogenated polyolefins, esters, silicones and fluorocarbons are sometimes used as base oils[1].

Lubricants both fresh and used can cause damage to the environment mainly due to their high potential of serious water pollution. The additives contained in lubricant can be toxic to flora and fauna. In used fluids the oxidation products can be toxic as well. Lubricant persistence in the environment largely depends upon the base fluid, however if very toxic additives are used they may negatively affect the persistence [9].

Impact of lubricants on the environment places primary emphasis on the used lubricants since they may contain materials that are harmful to life and the environment. Issues of lubricant conservation, used oil reclamation, reprocessing, disposal and oil biodegradability are being taken up by a number of researchers to mitigate adverse effects of oil on the environment [11].

IV. Cleaner Production Overview

Widely accepted definition of Cleaner production is continuous application of preventive environmental strategy to processes, products and services to increase the overall efficiency and reduce risks to humans and environment according to United Nations Environment Program (UNEP) in 1998 [6].

In production processes, it entails saving of raw materials and energy, elimination of toxic raw materials and reduction in the quantities and toxicity of wastes and emissions.

While, in product development and design, cleaner production seeks to reduce negative impacts throughout the life cycle of the product from raw material extraction to ultimate disposal. The basis is to make companies more resource efficient and less polluting. It is crucial that attitude change is inculcated in the entire workforce [6].

Options generated during assessment can then be reviewed for applicability and cost effectiveness.

There is now an upward-spiral of new environmentally related legislation. All this poses a challenge for organization to take cleaner production seriously as a source of competitiveness, it aids cost savings and reduces environmental liability on the company [3].

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V. Lube Oil Blending Plant (LOBP) Operations

The process of coming up with a mineral liquid lubricant is divided into two main processes which are upstream and downstream operations [15]. Where upstream involves exploration, mining and crude distillation refining to get lube base oil, whereas downstream entails raw material sourcing, storage, lube blending, packaging and marketing/ distribution.

Manufacturing involves the downstream operation of physically mixing the raw materials in a lube oil blending plant (LOBP).

In summary, the three major functions involved in the lube blending process sequence in are [15]:

1.Receiving and storage of base oils, additive and packaging materials

2.Physical mixing as per formulation sheet and agitation blending of base oil and additives, and filling of packaging containers with oil

3.Warehouse storage and distribution of finished lubricants.

Oil batches processed and transferred into holding tanks, then packaged into small packs and drums.

Mining has topped up as the major user of lubricants as they receive bulk lubricants from tankers in most cases [4]. There is need to provide them with closed loop used oil collection system on drainage into used oil tanks. Thus used and recovered oils can be compared and investigation into hydraulic leaks and engine malfunction can be done, at the same time taking action to protect the environment.

It is estimated that less than 45% of used engine oil is being collected while the remaining 55% is thrown by the end user in the environment.

VI. Lubricant Life Cycle

"Lube life cycle" means a holistic assessment of base oil production, manufacture, distribution, use and disposal including all intervening distribution steps necessary or caused by the lubricant's existence[14] . The concept also can be used to optimize the environmental performance of lubricants.

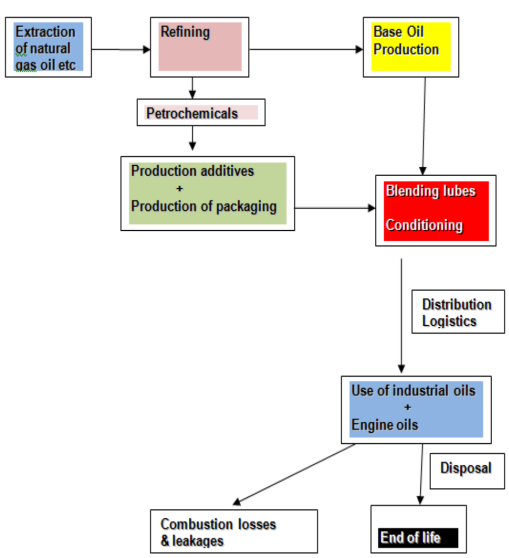

Fig. 1 Lubricants Product Life Cycle[10]

Lubricants Life cycle analysis methodology is used for identifying and reducing the impact of lubricant on the environment. With this approach, respect for the environment is built into the new product design right from the start [13].

From initial design to disposal of a lubricant, life cycle analysis enables examining and monitoring environment impacts arising from lubricant using ISO 14040 standard procedures [12].

A. *Synthetic lubricants and long drainage intervals*

Synthetic PAO lubricants have resistance to breakdown allows synthetic oils to be utilized longer than conventional oils in addition to systems being cleaner and lasting longer [1].

The first thing we can do is to not create so much used oil to begin with by taking advantage of the benefits that synthetic lubricants provide. We can protect our precious environment through generation of far less waste oil resulting in a considerable reduction in environmental contamination and damage.

B. *Extended or Condition-based Drainage Interval*

Extending the interval too far places the machine at-risk for wear and failure due to underperforming lubricant and/or excessive contamination levels. Factors such as operating temperature, presence of water contamination, aeration levels, contaminant ingestion rate and wear generation rate, along with propensity for risk and planning and scheduling windows all influence the decision [7].

C. *Leakage Management*

Leaky machines can cause injuries, fires, improper/slowed operation, quality defects and environmental damage, not to mention high labor and material costs. Machines leak due to improper design, operation or maintenance. Ideally, leakage should be managed by identifying its source and cause and by taking corrective actions to eliminate it[20]. Containment and guttering systems for leaked oil can be expensive to install and maintain, and they may be only marginally effective.

VII. Methodology

The Cleaner Production assessment dwells on two main parts of the lube life cycle which are the blending operation (LOBP), as well as application and disposal of the lubricants after use.

<u>LUBE BLENDING(LOBP) CP ASSESSMENT</u>

The quality of the effluent generated from the drainage system in the LOBP is monitored monthly as per existing environmental guidelines and is entered in a register specifically kept for that purpose and monthly returns of these effluent analysis. City Council Waste Management collects the liquid waste from for disposal on monthly basis for a fee.

Fig. 2 below outlines assessment at LOBP. The assessment of each discrete process was reviewed for reducing raw material consumption and waste generation.

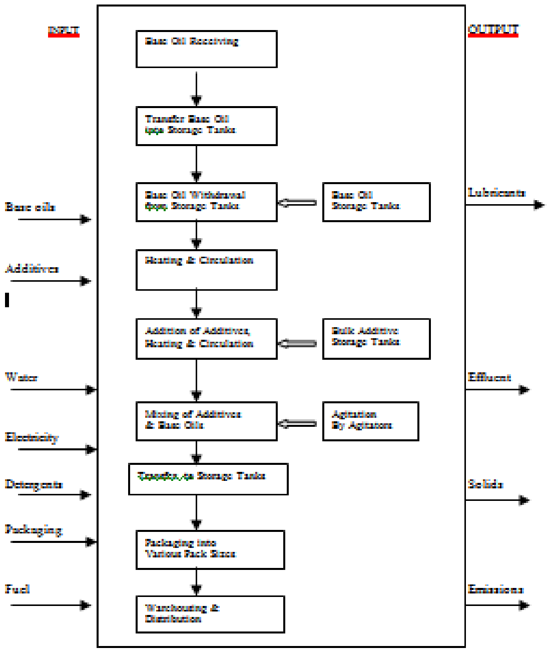

Fig. 2 LOBP CP assessment

According to the Fig. 2 the inputs are raw materials in form of base oils and additives, water, electricity, detergents and packaging materials. While the outputs include finished lubricants, effluent from floor cleaning and oil spills, air emission from base oil evaporation on agitation and solid waste from damaged packs and solid additives.

Sources of oil waste into drainage system noted during the pre-assessment phase were:

TABLE I
SOURCES OF OIL LOSSES

Area	Source of loss
Receipt & storage	Spills and leaks from hoses, couplings, pumps Spills from storage tanks Cleaning & draining
Agitation	Heating & pouring fumes Foaming Leaks from pumps, pipes & gaskets Oil splashes
Filling	Over filling Cleaning of filling machinery Damaged packages Machine break-down Inadequate guttering

Major consumers of energy are the conveyors and air compressors. Breakages, overfills and package breakages are responsible for oil losses, although the filling line is automated.

The intensity of resource consumption and waste generation is mainly on agitation and filling processes. This implies more effort has to be directed towards these two processes for Cleaner Production options to yield quick impact on implementation.

A. LOBP CP Options

Water

- Install sub meters
- Avoid running taps when not in use
- Use high pressure air not water to clean

Electricity management

- Insulation of tanks and pipes
- Install thermostats to reduce fumes
- Energy serving bulbs/tubes
- Energy Account Centers(EAC's).
- Use automatic shut-off valves
- Replacement of old motors (1983)

Product losses

- Guttering in agitation and filling sections
- Proactive maintenance

Training

Train staff in:

- Basic plant maintenance
- Water saving practices
- Electricity conservation methods.

B. LOBP CP Options Economic Evaluation

The resulting ranking after dropping the less viable options is:

1. Oil guttering in the LOBP (A)
2. Energy power sub-metering (B)
3. Water sub-metering (C)

The Cleaner Production concept can be adopted gradually to achieve permanent improvement towards greener production culture by all entrepreneurs and corporates for sustainable development. Thus the environment will be protected, economic efficiency of operations achieved and waste generation minimized. Thus oil guttering has been rated critical as it reduces waste into the environment.

C. LOBP CP options: Environmental & Technical weighting

Oil guttering: According to the three main CP options highlighted in section on economic evaluation and found to be viable in terms of cost benefit analysis, oil guttering is critical to cutting on loss of expensive base oil and reducing waste collection charges by the regulatory authority and is easy to install.

Energy management: This seeks to rectify leaking compressors in filling section, installation of automatic shut off valves to avoid re-blends and it is easy to install.

LUBES APPLICATIO AND DISPOSAL

This study was based on the opencast mining operation. The mine has a fleet of fifteen 40-tonne dumps trucks hauling ore from the opencast operation 15 km away to the processing plant. The Fig 3, below gives the flow chart of lubricants after delivery from the mine workshops. The major processes investigated were: storage, handling and disposal of used oil.

Used oil recovery is 55% of fresh oil used due to possible leaks and spills. Hydraulic hose bursts on the dump trucks is also a major contributor, where substantial amount of oil directly finds its way into the soil and water ways polluting the environment.

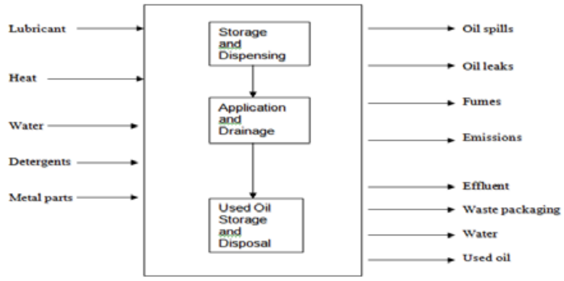

Fig. 3 Application and disposal flow chart

Temporary field workshops are a major contributor to throwing away of used oil direct into the environment as there are no oil separators to talk about. Also losses were due to leaking pumps and pipes especially for bulk storage. Partially closed valves cause leakages and faulty dispensers cause leaks. Decanting into old tins results in spilling. On drainage spills results from mishandling. Machinery vibration cause leaks especially for off-road dump truck operation like at the mine.

A. Application / Disposal CP Options

Cleaner production opportunities identified are mainly in the area of effective housekeeping where all forms of leakage are reduced to improve worker safety and minimize product losses as wastage to the environment.

B. Oil consumption

This may be a saving in terms of reduced oil stocks maintained at the mine workshop through the following:

1.Extended drainage from 250 hrs to 300 hrs
2.Synthetic lubricants with longer drainage
3.Computerized dispensing equipmentto reduce leaks, pilferage and unauthorized issues from bulk storage.
4.Use fortified hydraulic hoses
5.Use of biodegradable oils
6. Operator-based maintenance

C. Oil losses

Used oil losses can be minimized through
1.Mobile used oil bowser
2.Closed-loop used oil receiver pan / diaphragm / tank system

Prioritized list for CP options was done as follows to realize savings:

1.Fortifying hydraulic hoses
2.Extended oil drainage
3.Computerized dispensing equipment
4.Use of synthetic oils
5.Used oil bowser acquisition
6.Compressor / air line /pneumatic pumps repairs
7.Water: Housekeeping and training

The practical effort to reduce dumping of oil into the environment is real for the mine. Further environmental and technical considerations were done using the weighting System.

VIII. Recommendations

It was observed that recommendations fall into two categories which are process-based and resource-waste minimization. The process-based recommendations are lubricant or product focused. While the resource-waste minimization recommendations dwell on the related process inputs and supporting infrastructure involved.

A. Process-based CP recommendations

Note that the process flow disregarded the existence of LOBP and the user as separate entities but focused on the lubricant.

TABLE II
PROCESS - BASED CP RECOMMENDATIONS

Process and Cleaner Production Options
1**. Storage/storage**
*Carry out operator-based maintenance training
* Provide spill clean-up kits at off-loading bays
* Pave inside of storage farm bund wall to avoid oil soil pollution
* Install storage tank overflow mechanisms to avoid spills
2. Agitation
* Construct slopping floor for easy oil drainage
*Use solar or energy efficient tubes or bulbs for lighting
*Install automated meters and valves for batch mixing accuracy
* Provide oil resistant gloves and insist on use of goggles by operators
*Install temperature gauges to avoid over heating during agitation
3. Filling
*Provide hearing protection devices to operators
*Introduce operator-based maintenance to reduce jamming
*Provide mobile solid waste mesh bins for damaged packaging
*Improve product guttering to reduce oil waste
*Train operators on water, energy and oil waste minimization
4. Warehousing/bulk storage`
*Install flame proof electrical fittings to avoid fires
*Erect shed over drum storage platform
*Use FIFO for drum stocking and dispatch
*Operator-based maintenance for bulk storage (pumps)
*Provide spill clean-up kits at bulk loading bay
5. Distribution(LOBP to site)
*Install hydraulic tailgate lifter on packaged
*Mount dedicated off-loading pump & couplings
*Provide drivers with spill clean-up kits
*Modify bulk delivery trucks to carry used oil on return trips
6. Storage / Dispensing(site)
*Erect asbestos shed over stores drum platform
*Fit suction pumps on drums in bunded trays to avoid splashes
*Make lube supplier MSDS readily available in case of emergency
*Avail spill clean-ff kits in the workshop
*Institute operator-based maintenance for dispensing equipment
7. Application / drainage
*Consider use of synthetic lubricants to reduce waste oil generation
*Use biodegradable lubricants for drills and hydraulic oil
*Introduce condition based or extended drainage backed by tribology tests
*Use mobile bowser for used oil collection at remote workshop sites
*Acquire new efficient mobile plant with catalytic converters and scrubbers for reduced greenhouse gas emissions
*Avoid hose bursts through use of nylon sleeving, plastic spring guards and metal spring guards
*Use oil resistant gloves and use of goggles for the operators
*Acquire proper used oil collection pans and diaphragm pump
*Implement oil audits on key mobile plant
*Use water sprays to reduce dust ingestion by the equipment
8.Used oil handling and disposal
*Install closed-loop used oil collection of pan, pump and storage tank
*Use certified used oil vendors or lube suppliers with bulk truck to collect used oil form storage to reduce spills and frequency

B. *Resource-waste minimization recommendations*

These depart from the above because in that they are specific to the resource consumption to be reduced and can be applicable to a number of processes and are site specific. For this reason we have two tables for the blending operation and lubricant user site

TABLE III
LOBP RESOURCE-WASTE MINIMIZATION CP

Resource	Cleaner Production Options
1.Water	*Install sub-metering system for agitation and filling processes *Avoid running taps when not in use *Use high pressure water for cleaning *Use compressed air or brooms where necessary *Report and fix leaks in the plant once observed *Drill borehole as a cheaper source of water
2.Electric power	*Use energy saving tubes or bulbs for lighting *Use solar for lighting, and canteen / shower hot water system *Ensure effective insulation for tanks and pipes for elevated temp. *Create separate Energy Account Centers with own reduced consumption targets for agitation and filling *Install automatic shut-off(set-stop) valves to avoid off spec batches resulting in rework jobs *Replace old motors with high power consumptions. *Fix air compressor leaks in the filling section
3.Oil losses	*Improve guttering in agitation and filing sections *Introduce operator-based maintenance for pumps, couplings / flanges *Review pipe supporting to avoid excessive vibration

TABLE IV
MINE RESOURCE-WASTE MINIMISATION CP

Resource	Cleaner Production Options
1.Water	*Avoid running water taps and hoses not in use *Report and fix water leaks *Use water jet machine for cleaning floors *Use pressurized air or brooms instead of water
2.Electric power	*Use energy efficient tubes or bulbs in workshops *Fix compressor, pneumatic pumps and air line leakages in the workshop
3.Oil consumption	*Use condition based or extended drainage *Use synthetic lubricants for longer use *Install computerized dispensing equipment *Use nylon sleeving, plastic spring guards and metal spring guards to fortify hydraulic hoses against bursts *Use water spray on roads to reduce dust ingestion into m/c's * Introduce operator-based maintenance for mobile plant
4.Oil losses	*Acquire mobile used oil collection bowser for remote sites * Install closed-loop used oil collection system of receiver pan, pump and storage tank

IX. CONCLUSION

Use of biodegradable lubes are focused on technology changes to protect the environment in case of remote site as the oil breaks into natural substances on spilling or leaking into the environment. This been recommended for rock drills in opencast mining. While controlled high temperature used oil burning is required for effective oil disposal

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