Assessment and Implementation of Cleaner Production Practices in Petroleum Lubricants Industry Value Chain in Zimbabwe

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Abstract: ***This paper is a study of Cleaner Production Assessment in the Petroleum Lubricants Industry value chain done in Zimbabwe. It focuses on opportunities available to reduce negative environmental impacts of lubricants throughout the value chain from blending to disposal. Effort was made to investigate existing cleaner production practices by manufacturers and users. Issues on base oil substitution, minimizing oil losses during and after manufacturing, raw material and energy consumption reduction, and environmentally friendly used oil disposal were reviewed as way forward for effective Cleaner Production for the industry .This study acts as a resource for managers in the lubricants industry both manufacturers and consumers to understand Cleaner Production aspects and incorporate CP practices in their operations for regulatory compliance, environmental protection and business competitiveness in terms of savings .***

Keywords: blending, lubricants, cleaner production, savings, disposal

1. 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. 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 [1], a rather less attention has been paid to pollution resulting from lubricants on disposal [8]. It would seem, therefore, that further investigation is needed to explore the lubricant products impact on the environment right from manufacturing to disposal. It is imperative that an investigation is done on how cleaner production strategy can be applied to mitigate the lubricants' impact on the environment and resulting in required regulatory compliant practices [6].

Cleaner production practices are fairly not common in the local industry, where waste disposal involves taking and dumping garbage at the major landfills. This includes waste generated by major users of lubricants. Thus soil degradation and water contamination result. 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. The assessment of cleaner production practices in the petroleum lubricants industry in the country, seeks to get recommendations that reduce the impact of lubricants on the environment from "cradle to grave" [3].

2. Justification of Study

Unlike petroleum fuel which is burnt and emitted as gaseous by-products to the environment, for which exhaust-system catalytic converters have since been fitted to vehicles to release less harmful gases. Also low emission drive by Original Equipment Manufacturers (OEMs) means the more harmful substances escape into the lubricants in engine oil application [7]. Thus now on disposal, used oil loaded with these is normally dumped as liquid waste. This poses a serious environmental damage in form of soil degradation, water contamination and interference with ecosystem balance [5].

In year 2011, 21 million liters of liquid lubricants was sold to users according to industry records and a third of this is disposed to the environment in various segments of economy. This is not a sustainable level of waste disposal.

Producers should be accountable for disposal of their products. A variety of options are going to be considered on handling this menace as manufacturers collaborate with end users for sustainable development.
Users of the lubricants are mines, contractors, manufacturers, franchised workshops, truckers, independent garages and individual motorists are scattered around the country [1].

3. Lubricants impact on environment

Lubricants both fresh and used can cause considerable damage to the environment mainly due to their high potential of serious water pollution [8]. 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 [5]. The research was done in two parts which are: Part One – Lube blending and Part Two - Application and disposal.

PART ONE

4. Lubricants blending

The process of coming up with a mineral liquid lubricant can be divided into main processes which are upstream operation and downstream operation [1]. Where upstream involves exploration, mining and crude distillation refining to get lube base, whereas downstream entails raw material sourcing, storage, lube blending, packaging and marketing/ distribution as show in the diagram below.

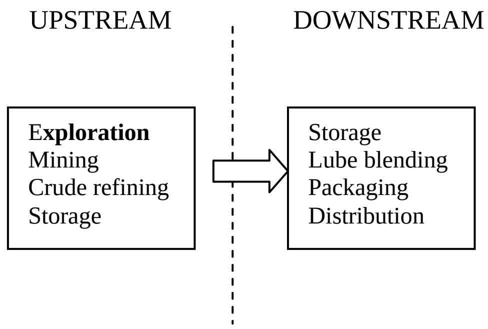

Figure 1: Lube Oil Processing Phases

Local manufacturing involves the downstream operation of physically mixing the raw materials in a lube blending plant and in Zimbabwe this is only currently happening at BlendCo in Harare. Thus local blending capacity is exceeded by market demand hence 50% of lubricants get into the country as finished product mostly from South Africa. Synthetic range originates from Europe and Asia because of the technology involved. All the additives used are imported from South Africa.

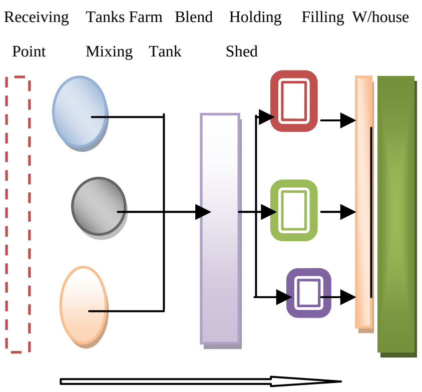

Figure 2: Blending Yard Product Flow

In summary the three major functions involved in the lube blending process sequence are [10]:

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.

5. Cleaner Production Assessment

The Cleaner Production assessment dwells on two main parts of the lube life cycle which are the blending operation and its various discrete processes, as well as application and disposal of the lubricants after use. This is in line with the extended producer responsibility (EPR) concept gaining enforcement on the legislative front.

The four-stage assessment steps: pre-assessment, assessment, feasibility and implementation will be applied to these two identified areas in this chapter:

Part One – Blending Operation for BlendCo.

Part Two – Application and disposal for Opencast Mine which is the main customer of BlendCo, for follow up on the application and disposal CP options available.

Before the full assessment, a cleaner production pre-assessment for the plant was carried out with the aim of setting the plant-wide CP goals, developing process flow charts, evaluating the general inputs and outputs and selecting an audit focus [4]. This involved walking around the entire processing plant in order to gain a sound understanding of all the processing operations and their interrelationships.

5.1 BlendCo operation review

BlendCo is currently the only operational blending plant in Zimbabwe as of 2011. It produces 14 different kinds of lubricants these include the automatic transmission fluid, engine oils that comprise the mono-grade and multi-grade oils for use in both diesel and petrol engines and all ranges of industrial gear oils. Other products include all ranges of hydraulic oil, universal tractor oil, gear oils 80W90 and 85/90 and 85/140 and such specialized oils like the two stroke oils. BlendCo of late also introduced its own brand of products.

BLENDCO is operating at 50 percent of its capacity. It has a staff complement of 65 for its operation. The company has a plant that has a maximum capacity to blend two million liters a month producing a combination of products that are packaged in 200ml, 500ml, 5 liter, 20 liters, 210 liter, 1000 liter containers as well as bulk off take facility. For the smaller packs up to drums there is an automated filling and capping facility. The production is based on 1-eight hour shift per day for 5 days a week. Processes overview of the are shown in Figure 3

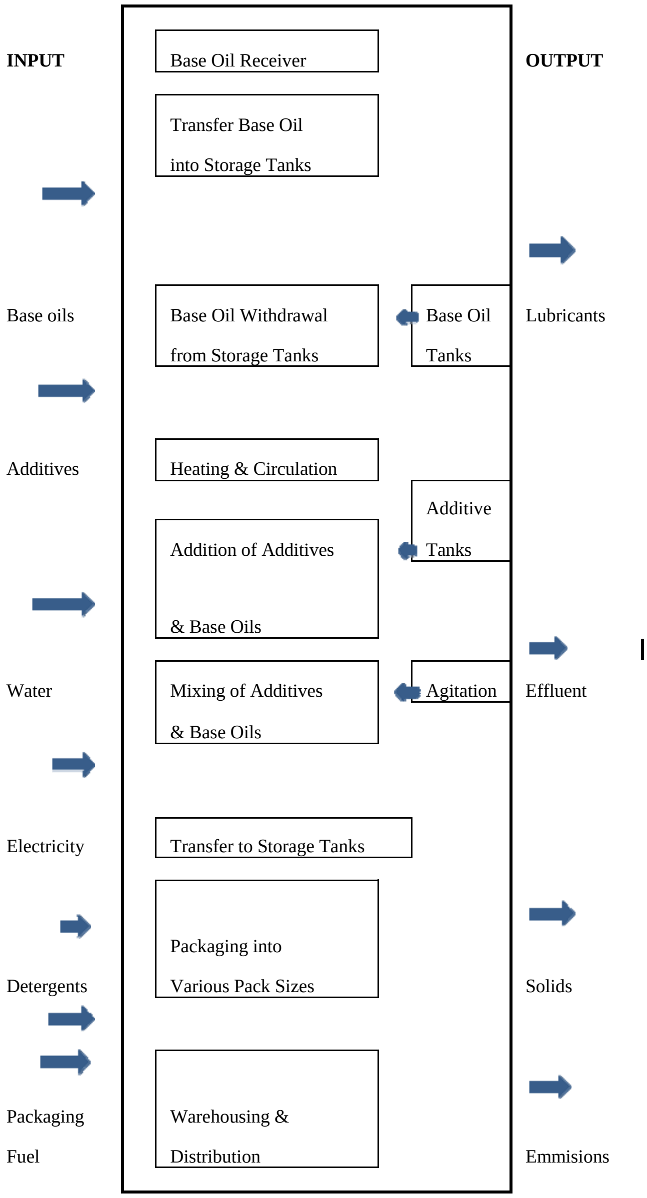

Figure 3: Lubes Blending Process Flow Chart

5.2 Blending: CP Pre-assessment

A walk-through was conducted with selected members of the team using the checklist and taking notes on observations made. 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. Products are distributed to customers as packs or bulk in tankers.

5.3 Blending: Cleaner Production Assessment

Following up on the highlights made during pre-assessment stage, focus was directed at quantifying losses through use of material balance. This enables the generation of cleaner production options supported by numbers [11]. By using a Cleaner Production philosophy to tackle pollution and waste problems, the dependence on 'end-of-pipe' solutions may be reduced or in some cases, eliminated altogether. Monthly consumptions of water, electricity as well as oil losses incurred are as given below in Table 1 for various processes involved. The monthly figures used are just the averages of the individual months for year 2011.

Table 1: Blendco monthly resource consumption

Process	Oil losses (lt)	Water(lt)	Energy(kWh)
Storage	2 250	14 400	1 584
Agitation	4 500	81 600	4 963
Filling	7 500	78 400	3 696
W/housing	750	1 600	750
Consumption per Unit (lt)	*0.015 lt*	*0.160 lt*	*0.01056 k Wh*

The various consumptions per unit production shown in the Table 1 are reduced and used as a measure for improvement on monthly basis [3]. The following sections highlight the areas where effort is focused on for Cleaner Production options [9].

Water usage: From above, filling and agitation processes use 91% of the water amount consumed per month. Thus Cleaner Production effort should seek to redress the current water consumption per unit production from 0.16 liters to a reduced figure. Sub-metering of the two sections as well as training for the operators has been recommended for this improvement to be realized.

Electricity consumption: Electricity has wide application in agitation, filling and receiving/storage, for which three (3) Energy Account Centers are going to be created and separately monitored to reduce the current energy consumption per unit production from 0.01056 kWh. Replacing old agitator motors and fixing leaks on the compressors may be considered to reduce power consumption.

Oil losses: Oil losses are a source of raw materials and they increase charges for wastage oil collection if volumes are big. The current level of 0.015 liter per unit production can be reduced by paying particular attention to agitation and filling processes where leaks and damaged packs are cause for concern. Maintenance has to be stepped up to rectify the sources as well as improving the guttering in the filling shed.

5.4 Blending: Cleaner Production Feasibility and Implementation

The mostly used economic tools [10] for evaluation are the payback period method, the net present value (NPV) and internal rate of return (IRR). These are widely applied to evaluate viability of the identified Cleaner Production options to be adopted as shown in Table 2.

6. BLECO CP Options economic evaluation summary

As shown in Table 2, the CP options have been put in order of attractiveness for each resource under consideration to summarize the calculations in sections above. It was noted that on the whole the overall payback period is less than one year for most options. IRR % for a greater number of options could not be calculated for paucity of data and only payback period and NPV methods were used.

Table 2: Economic ranking of BLENDCO of CP options

CP Option	Savings	Investment	Payback	NPV	IRR
ENERGY SAVINGS					
1. Fixing compressor leaks	$1 152	$150	0.13 yrs	$853	-
2. Energy efficient tubes	$1 014	$120	0.12 yrs	$761	-
3. Solar panel installation	$1 520	$880	0.60 yrs	$442	-
4. Energy sub-metering	$2 027	$1 600	0.79 yrs	$163	27.2%
5. Automatic shut-off valves	$1 013	1.18 yrs	-$-		
6. Inefficient motor replac	$2 382	$15 000	6.30 yrs	-$1292	-
WATER SAVING					
1. Water sub-metering	$460	$260	0.60 yrs	$140	33.8%
2. Housekeeping / training	$115	$600	5.22 yrs	-$500	-
3. High pressure water	$345	$1 400	4.00 yrs	-$1099	-
OIL LOSS OPTIONS					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The resulting ranking after dropping the less viable options is:

1. Oil guttering in the BlendCo (A)
2. Energy power sub-metering (B)
3. Water sub-metering (C)
4. Fixing compressor leaks
5. Use of energy efficient-tube
6. Solar panel installations

Table 3: BLENDCO CP options: Environmental & Technical weighting

Criterion	Wght	Oil guttering Score	Oil guttering W/sco	Energy mgt Score	Energy mgt W/scor	Water mgt Score	Water mgt W/scor
1.Reduced oil waste	3	+3	9	0	0	0	0
2.Reduced waste charges	3	+3	9	0	0	0	0
3.Reduced reblends	3	0	0	+3	9	0	0
4.Reduced water use	1	+2	2	0	0	+3	3
5.Reduced noise problem	3	0	0	+1	3	0	0
6.Reduced energy use	2	0	0	+3	6	0	0
7.Easy to install /maintain	3	+3	9	+1	3	+3	9
Weighted sum			29		21		12

*-3= lowest rank, 0= no change, +3 = highest rank(preferred)

Replacement of electric motors though considered not viable, it can be done in phases for feasibility. The Cleaner Production concept can be adopted gradually to achieve permanent improvement towards greener production culture. After economic screening, weighting in Table 3, seeks to evaluate the environmental and technical suitability of implementing each options against a number of competing organizational demands.

Oil guttering: According to the three main CP options highlighted on economic evaluation [11] and found to be viable in terms of cost benefit analysis, oil guttering is also critical to cutting on loss of expensive base oil and reducing waste collection charges by the municipal authority. Technically, it is considered to be easy to install to ensure product recovery in the agitation and filling section.

Energy management: Second in ranking is the energy sub metering [9] which seeks to rectify leaking compressors in filling section, installation of automatic shut off valves to avoid re-blends and it is easy to install the meters on filling and agitation sections. But it has a low bearing on the environmental protection and waste generation.

Water sub metering: This is considered last in the weighting ranking. As most of the water related issues are covered by housekeeping and training. Also it is easy to install meters on agitation and filling sections.

This gives oil guttering at BlendCo, high implementation priority over other CP options available. Hence its implementation for immediate reduced impact on the environment.

7. BlendCo Savings

<u>Savings</u>	<u>%</u>
Oil losses	47
Energy power	48
Water	5

The percentages above show the levels of potential savings that is accrued by reducing water and energy consumption, and raw material wastage [9] in the BlendCo. Trend analysis is done on monthly basis to track the progress with Cleaner Production team coordinating the focus to attain set targets. Emphasis is on energy and oil loss reduction as critical because of the potential they show in terms of possible savings. It is indicated that some USD19 026 savings can be achieved and reduce the cost of running the plant, which in its own is a source of competitiveness against lube imports for BlendCo.

PART TWO

8. Application and disposal

This section of the Cleaner Production is based on the Opencast mine operation [2]. The company is in the business of mining and processing coal, production of coke and related by-products. It produces 5 million tons of coal per annum for domestic and export markets. The company employs about 3 200 people. Its major customer is the power supply utility Zim Power Station situated adjacent to the mine.

According to the Opencast Mine manager, the company has a quality management system ISO 9001: 2000 obtained in 2005. Quality review meetings are done every quarter. On environment the mine has invested time and funds to achieve harmony between operations and the ecologically sensitive environment. Their main operation is opencast mining.

Where the mine has a fleet of fifteen 40-tonne dumps trucks hauling coal ore from the opencast operation 15 km away to the processing plant. Other complimenting pieces of machinery include front-end loaders, graders, bulldozers and excavators. The opencast operation workshop has a 24-hour maintenance for the mobile equipment manned by qualified technicians. The consumption of lubricants about 31 000 liters per month according to workshop records. Lubricants are delivered both bulk and packaged products.

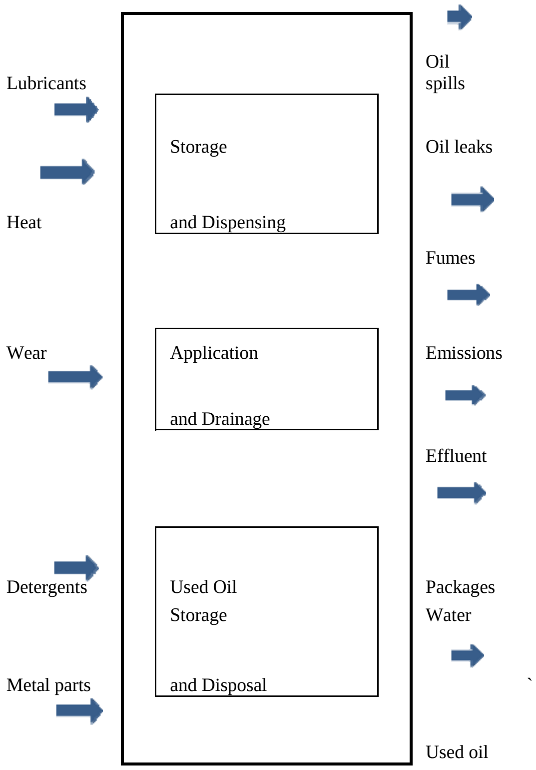

Figure 5: Application and disposal flow chart

8.1 Application and disposal: Pre-assessment

The mine seeks to comply with all applicable current and future environmental laws and regulations, to strive to attain international standards where no local standards exist and to maintain contact with legislating authorities. Currently they are working on ISO 14000: 2004 accreditations. Used oil recovery is 55% of fresh oil used [1] and the target is to get 75% by reducing possible leaks and spills due to mishandling and poor machine maintenance. Hydraulic hose bursts on the dump trucks is cause for concern at the Opencast mine.

8.2 Application and disposal: Cleaner Production Assessment

The Opencast mine operation is critical as it provides 80% of the mine output. The key equipment is made of fifteen (15) 40-ton dump trucks which collect ore from the operations. These are closely monitored to avoid bottle necks in production; they are scheduled for preventive maintenance after every 250 hours of operating. They are checked for oil levels and cleaning on daily basis or after every 3 shifts. Lube tanks capacities and consumptions are given in the in the table below:

8.3 Opencast operations analysis

Table 4: Lube consumptions by oil type

Oil Application	Tank (lt)	Oil Usage(lt)
Engine Oil	25 000	7 000
Hydraulic Oil	50 000	16 000
Gear Oil	15 000	4 000
Diff. Oil	10 000	2 000
TOTAL	*90 000*	*31 000*

Table 5 below shows the average monthly consumptions of water, energy and oil losses at the Opencast mine. The table also gives the resource consumption for production of a ton of coal.

Table 5: Summary of resource consumption and oil losses

Process	Oil losses(lt)	Water(lt)	Energy(KWh)
Storage/Dispensing	1 550	12 000	3 250
Application/Drainage	9 300	888 000	2 600
Used oil Handling/ Storage	3 100	300 000	650
Consumption per Unit production	*0.0465 Lt/ton*	*4 lt/ton*	*0.02167 kWh/ton*

In the following sections effort is made to highlight areas of potential savings, so that the cost of producing a ton of coal can come down for competitiveness in production.

Oil Consumption: Oil consumption for the month is 31 000 lt, hydraulic and engine oil constitute the bulk of the volume. CP options like use of synthetic oil, extended drain, use of protected hydraulic hoses can reduce the consumed volume per ton down from 1.239 lt. Thus in the long run the total volume of lubricants consumed per month can actually come down if hydraulic hose burst are minimized and engine oil drainage extended beyond 250 operating hours.

Oil losses: Oil losses are unintended leakages from the system; it is during application that the greater amount of oil is lost. Hence need to use extended drain, synthetic oils and having an effective hose burst management system in place to ensure that the same lost oil does not pollute the environment. Oil losses entails used oil spills at site operation as it is no accounted for in the used oil collected. Current oil losses per ton of coal produced is 0.0465 liters.

And this can be reduced to ensure reduced environmental pollution.

Water consumption: Water is mainly used for cleaning the mobile plant , cleaning the workshop floors and spraying the main yard to reduce dust ingestion by trucks and workshop. About 4 lt of water is used for each tone of coal produced. And this can be reduced through improved housekeeping and better water management system in the workshop.

Energy consumption: Extensive lighting on the roads and the operations sites consumes most of the energy as the operation is on 24 hours of the day. Use of power efficient tubes or bulbs will go a long way in reducing the current level of energy usage which is 0.2167 kWh per ton produced. Servicing the compressor, pneumatic pumps and all leaking air service lines will cut power used by the compressor motor.

9. Application and disposal: Cleaner production 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. Overall oil consumption has to come down at the same time reducing oil losses during use until it is well disposed off. Other resources such as water, electric power and fuel have to be revisited for efficient consumption [3].

The operation at Opencast mine is intensive as lubes are dispensed 24 hours a day, trucks are water cleaned when due and machine compartments oil levels checked and re fuelled. An 11kW motor compressor is installed to run 5 dispensing heavy duty pneumatic pumps. The workshop is heavily lit as well as the whole 10km road to the drag line. The same is done for the operations site where some equipment is located to facilitate round the clock production.

Use of biodegradable oils: There are instances where the oil cannot be effectively managed without getting into the environment such as in case of the rock drill oils [8]. Where the tools are pneumatically driven and excess lubricant spills into the soil at operating sites. In such cases the biodegradable oils are required so that on spillage, the oil breaks down into natural occurring elements which are harmless to the environment.

Operator-based maintenance: Operators to be trained on basic motor maintenance, so that they can do checks regularly for fluids levels, hydraulic leaks, tyre condition, unfamiliar engine sound, loose parts and tighten them at the beginning of the shift.

Oil losses: It is good for the environment to minimize oil losses, and ensure that it is collected and sold to certified vendors for used oil a source of energy in some industries [1]. The present price for used oil is $0.15 per liter.

Mobile used oil bowser: At the operations stationary equipment such as the drag line, graders, compressors, excavators, bulldozers and front-end loads are serviced in situ by the technicians. These consume about 8 000 lt of oil per month. To avoid waste polluting the environment one of the existing 5 000 lt water bowsers can be dedicated for collecting used oil drained [2].

10. Opencast CP economic evaluation

Table 6 puts the various CP options under each resource savings according to the economic viability rating. Payback period and NPV were mainly used to rank the options as in most cases the IRR rate could not be calculated except in a few instances, where it come out above 15%. The most attractive savings were generated under oil consumption, followed by oil loss minimization, then energy and finally water savings. All the options gave payback period which is less than one year and NPV's which are all positive.

Table 6: Economic ranking of Opencast CP options

CP option	Savings/yr	Investment	Payback	NPV	IRR
WATER SAVING OPTIONS					
1. Housekeeping / training	$1 728	$600	0.35 yrs	$902	-
2. Water-jet cleaning m/c	$1 728	$700	0.40 yrs	$802	-
3. Pressurized air	$864	$80	0.10 yrs	$671	-
ENERGY SAVING OPTIONS					
1. Compressor leak repairs	$1 900	$750	0.40 yrs	$902	-
2. Energy efficient tube	$1 092	$650	0.60 yrs	$299	68.7%
OIL CONSUMPTION SAVING OTPIONS					
1. Fortifying hydraulic hoses	$302 000	$75 000	0.25 yrs	$187887	-
2. Extended drainage	$186 000	$10 800	0.10 yrs	$150939	-
3. Use of synthetic lubricants	$558 000	$372 000	0.70 yrs	$113 217	36.2%
4. Computerized dispensing	$55 800	$6 000	0.11 yrs	$42 521	-
OIL LOSS MINIMIZATION OPTIONS					
1. Used oil bowser	$7 920	$2 500	0.32 yrs	$4 386	-
2. Used oil system	$5 580	$4 200	0.75 yrs	$625	34.1%

The following came up as prioritized list for CP options to be done 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 overall payback period for the Opencast mine is very small as the practice is that the suppliers meet the cost of equipment over years as total package to their customers. The practical effort to reduce dumping of oil into the environment has been real for Opencast mine if they implement the recommendations and Cleaner Production opportunities made available to them by this research work.

11. Opencast mine CP options: Environmental & Technical weighting

After the CP options economic evaluation above the further environmental and technical considerations are done as presented the Table 7 below [4]:

Table 7: Opencast mine CP options weighting

Criterion	Wght	Fortify hoses Score	Fortify hoses W/scor	Ext. drain Score	Ext. drain W/scor	Oil bowser Scor	Oil bowser W/scor
1.Reduced oil waste	+3	+1	3	+3	9	+1	3
2.Reduced oil loss	+3	+3	9	+1	3	0	0
3. Reduced pollution	+3	+2	6	+3	9	+3	9
4.Reduced exposure	+2	+1	2	+3	6	+2	4
5.Reduced water use	+1	0	0	0	0	0	0
6.Reduced oil loss	+2	0	0	+3	6	+3	6
7.Easy installation	+3	+3	9	+3	9	+1	3
Weighted Total			29		42		25

*-3 = lowest rank, 0 = no change, =3 = highest rank (preferred)

Extended drainage: If applied correctly it does not require any capital equipment and it results in about reduced usage of oil by about 5 167 lt per month. This means less oil is thrown away to the environments as used oil. Despite it being ranked low on the economic evaluation is substantial in environmental protection as it reduces waste generation in form of used oil [2].

Fortify hoses: Technically they are easy to install hence an attractive option. Hydraulic bursts can be really reduced resulting in minimized oil losses to the environment. Currently the hoses and oils have been sacrificed instead of hose fortifying efforts. This comes second to extended drain as it is focused on the hydraulic oil consumption only and not the machine compartments.

Used oil bowser: This is ranked third on the environmental premise that it is purely an "end-of –the pipe" solution. In reality any used oil collected at remote sites could have ended up polluting the environment if not so collected. Technically the bowser is not attractive as it is associated with handling waste at the expense of core business.

Computerized dispensing: This is ranked fourth and not on the table, as it is technically involving as an expensive contractor has to be called to do the job. Leaking can also be minimized by assigning internal artisan to fix. In environmental terms leaks are of limited nature and can be handled internally.

12. Opencast mine Savings

Savings	%
Oil losses	16%
Oil consumption	74%
Water	6%
Energy	4%

The analysis above shows the potential savings that can be achieved by reducing oil consumption, oil losses, water usage and energy consumption [4]. Most of the opportunities are on oil consumption through use of extended drain. Followed by limiting on oil losses for cost effective operation. While to a smaller extent, water and energy usage can also contribute to the savings as well. If the various Cleaner Production initiatives are taken on board the cost of producing coal will certainly come down from the current $58 per ton. This be a source of competitiveness against other regional suppliers of coal. It must also be noted that the major contributors to possible savings which are oil consumption and oil losses aspects have a direct positive impact on the environment. Thus the business prospers and the environment is protected at the same time [11].

13. Research 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.

13.1 Resource-waste minimization recommendations

These are specific to the resource consumption to be reduced and can be applicable to a number of processes like in this case energy reduction recommendation can be applicable to agitation and filling sections. Also it was noted that the resource-waste minimization recommendations are site specific. For this reason we have Table 8 for the BlendCo and Table 8a for the lube Opencast site**.**

Table 8: BlendCo resource-waste minimization CP recommendations

Resource and 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 s pec 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

While the process-based recommendations can be considered generally qualitative for similar lube processes, resource-waste minimization recommendations open up the resource parameters to be considered for savings calculations to be done [3]. Hence CP options were outlined for both Part One and Part Two, but only quantitative savings were generated when considering individual efforts to minimize resource wastage.

Table 8a: User resource-waste minimization CP recommendation

Resource and 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

The importance of resource-waste reduction was abundantly reflected, as the extent to which a resource is consumed indicated the potential for savings inherent in reducing that particular resource consumption or wastage.

13.2 Process-based CP recommendations

Table 9 summarizes the general process-based recommendations generated by this research work for the eight discrete processes/section identified during the exercise. Note that the process flow disregarded the existence of BLENDCO and the Opencast mine as separate entities but focused on the lubricant.

Table 9: 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

14. Conclusion

Research data revealed resource consumption patterns which in turn led to possible CP opportunities which generate savings [3] in the operations. Investing in Cleaner Production, to prevent pollution and reduce resource consumption is more cost effective than continuing to rely on increasingly expensive 'end-of-pipe' solutions. When Cleaner Production and pollution control options are

carefully evaluated and compared, the Cleaner Production options are often more cost effective overall. The initial investment for Cleaner Production options and for installing pollution control technologies may be similar, but the ongoing costs of pollution control will generally be greater than for Cleaner Production [8]. Furthermore, the Cleaner Production option will generate savings through reduced costs for raw materials, energy, waste treatment and regulatory compliance.
Rigorous economic, environmental and technical evaluation of each CP option attractiveness were carried to justify if the options recommended are practically feasible or not for implementation

15 Further Researches

Current practice is that the lubricant is drained at the end of the day, no matter how extremely extended the drainage period has been. This is so, as the additives get used up and the lubricant capacity to protect metal components is diminished [7]. Thus posing used oil disposal challenges to the industry. Biodegradable lubricants are still work-in-progress [5], as its risks after use are dependent on original additive heavy metal oxidation compounds resulting after use.Hence the issue of green lubricants requires further investigation probably, with serious consideration of solid lubricant using the nano - technology, can be the much sought after future environmental solution, where drainage can be eliminated totally**.**

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