Feronia Waste Water Treatment Assessment Report

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Feronia Incorporated Services Ltd

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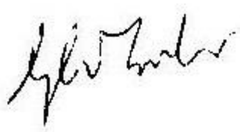
Graham Trusler	Report Reviewer		September 2015

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1 Introduction

Feronia PHC (Feronia or the Company) is an agricultural production and processing business in the Democratic Republic of Congo (DRC). The Company operates three palm oil plantations at three locations within the DRC. Two of the locations (Lokutu and Yaligimba) are situated adjacent to the Congo River and the Boteka Plantation is located adjacent to the Momboyo River, which is a tributary to the Ruki River and ultimately the Congo River. Activities at the oil palm operations include: plant nurseries, plantations, processing mills, a seed research station and storage and shipment facilities.

Products produced include crude palm oil and palm kernel oil. These products are transported by barge to Kinshasa.

The Environmental and Social Scoping Report produced in August 2014 by the Fedderson Consulting Pty Ltd Group (FCG) indicated that no formal water management system is currently required or in place. A few “executive” houses have septic tanks with French drains, while the majority of toilet facilities are pit latrines. Irrigation is limited to small scale manual watering in the plant nurseries. Storm water control at the mills is not an issue as there are no large paved areas which can concentrate the rainfall runoff (FCG, 2014).

Palm oil mill effluent (POME) generated as part of the production process is currently not treated at any of the locations, although an informal ponding system has been constructed at Boteka (as described below). The POME is discharged into the river system (FCG, 2014):

- Boteka – Approximately 6.25 m^3/hour of effluent is discharged into ponds that have been constructed. POME is retained in the ponds and is ultimately discharged to the Momboyo River, a tributary of the Ruki River and ultimately the Congo River, which is approximately 500 m to 750 m wide at the point of discharge;
- Lokutu discharges approximately 15 m^3/hour of POME into Congo River, which is approximately 3 750 m wide at the point of discharge; and
- Yaligimba discharges approximately 18.75 m^3/hour of POME into a narrow channel (initially brick-lined). This channel conveys the POME several kilometres to a river which is approximately 175 m to 350 m wide at the point of discharge. The effluent is significantly diluted by several tributaries which discharge into the channel, prior to discharge into the river.

The Scoping Study document states: “although there is no visible evidence of long term environmental damage despite many years of operations, treatment should be provided in order to implement current good practices that are implemented in the industry”. Limited information regarding the quality of the effluent discharged from each of the three mills is available.

2 Scope of work

The overall objective of this study is to give technical advice on how to reduce the biochemical oxygen demand (BOD) of the palm oil mill effluent (POME) to 50 mg/L (from 500 mg/L), which is the longer term objective set by Feronia in order to meet good international industry practice. BOD is the amount of dissolved oxygen required to meet the metabolic needs of aerobic organisms in water rich in organic matter.

The scope of work undertaken by Digby Wells comprised:

- A site visit to the three palm oil mills;
- Discussions with Feronia staff about the plans for waste water management;
- A review of a technical report produced by Feronia, entitled “Proposal to Manage Palm Oil Mill Effluent (POME) over time to achieve good international industry practice (GIIP)”; and
- A short literature study to determine what type of technically and financially feasible options are available to treat the POME.

3 Characteristics of Palm Oil Mill Effluent (POME)

The literature study defined POME as the waste water that originates from the palm oil milling activities including the sterilisation process, crude oil clarification and cracked mixture separation process. Various authors described the effluent as a concentrated effluent with a distinctive odour and colour (TY Wu et al, 2010, Azmi et al, 2014; Ji et al, 2013; Wang et al, 2015). It is characterised by high Chemical Oxygen Demand (CODs), Biochemical Oxygen Demand (BODs) and volatile solids. Wang et al (2015) characterise the effluent as having the following characteristics:

- Chemical Oxygen Demand (COD) of approximately 44 300 – 102 000 mg/ℓ;
- Biochemical Oxygen Demand (BOD) of approximately 25 000 – 65 000 mg/ℓ;
- Salt and suspended solid content of 18 000 – 46 011 mg/ℓ;
- An acidic pH of 3.4 – 5.2; and
- Oils and grease concentrations of 4 000 - 9 341 mg/ℓ.

The characteristics of typical POME were also given by Setliadi et al, 1996 as:

- Chemical Oxygen Demand (COD) of approximately 15 103 – 65 100 mg/ℓ;
- Biochemical Oxygen Demand (BOD) of approximately 8 200 – 35 400 mg/ℓ;
- Salt and suspended solid content of 16 580 – 94 106 mg/ℓ; and
- Oils and grease concentrations of 2 200 - 4 300 mg/ℓ.

Whilst these figures differ from those given above by Wang, they do indicate the broad issues associated with POME, the variability of the effluent and also highlight the major issues which need to be addressed.

According to TY Wu et al, 2010, the characteristics of POME may vary considerably for different batches, days and factories, depending on various factors such as processing techniques and the age or type of fruit, climate and condition of the palm oil processing. Seasonal oil palm cropping, activities of the palm oil mill (such as occasional public holidays, closure of the mill, operation and quality control of individual mills) can also influence the quality and quantity of the discharged POME.

Although no chemicals are added to the effluent as part of the process, the effluent will have a detrimental impact on the receiving water environment if it is discharged directly to a watercourse due to its large oxygen depleting capability on the aquatic systems. However, due to the immense size of the Congo River the significance of the impact may be localised along the riparian zone and is currently negligible. It is however important to Feronia that the effluent be treated according to good international industry standards and best practices.

During a site visit Digby Wells took samples of the effluent generated from the mills (3 samples) that are discharged to the river environment and the results are presented in Table 1. The samples were transported back to South Africa for analyses; however, only one sample (Boteka) had enough volume that could be used to determine the BOD.

The quality of the POME for the organic variables of the three plants was compared with the POME quality found in the literature in Table 1. It was found to be significantly different. The reason for this may be attributed to the fact that the samples taken were not kept cool and were not analysed within 24 hours at a laboratory due to transport difficulties from the DRC. Due to the organic nature of the effluent the breakdown of the organic material continues after sampling until there is no organic matter left and this will influence all the organic variables. The Yaligimba effluent also appears to be very different from the other two mills. This may have been due to the operations occurring at the mill at the time. The above results should be used as indications of the mill effluent as there may be significant variables depending on the mill operations at the times of sampling.

What can be seen from the Digby Wells and the Feronia sampling is that the results are highly variable.

The POME was also compared with the World Bank Group's Environmental Health and Safety Guidelines for the Vegetable Oil Production and Process (dated February 12, 2015).

Table 1: Effluent quality results collected from the various palm oil mills during January 2015

Variable	Boteka	Yaligimba	Lokutu	Typical Concentrations of POME (Wang)	WB EHS Guidelines Effluent standards
pH	6.82	6.88	4.13	3.4 - 5.2	6 - 9
EC (mS/m)	434	3.44	595		
TDS (mg/ℓ)	2 250	23	3 051		
BOD (mg/ℓ)	2 500			25 000 – 65 000	50
Total Suspended Solids				18 000 – 46 011	50
Cl (mg/ℓ)	297	5.75	416		
SO_4 (mg/ℓ)	<0.04	0.567	393		
NO_3 (mg/ℓ) as N	0.281	0.091	0.04		
NO_2 (mg/ℓ) as N	0.02	0.059	<0.002		
NH_4 (mg/ℓ) as N	0.288	1.35	0.567		
Total nitrogen (mg/ℓ) as N					10
Orthophosphate PO_4 (mg/ℓ) as P	64.2	0.64	43.3		
Total phosphorus (mg/ℓ)					2
F (mg/ℓ)	0.793	0.119	0.146		
Ca (mg/ℓ)	125	2.11	225		
Mg (mg/ℓ)	107	0.947	330		
Na (mg/ℓ)	199	1.47	11.7		
K (mg/ℓ)	647	3.79	706		
Al (mg/ℓ)	0.308	<0.003	0.408		
Fe (mg/ℓ)	2.5	<0.003	56.8		
Mn (mg/ℓ)	<0.001	<0.001	5.1		
Oils and grease (mg/ℓ)				4 000 - 9 341	10

Table 2: Effluent quality results collected from the various palm oil mills by Feronia

Variable	Boteka 4/8/2015	Yaligimba 4/8/2015	Yaligimba 4/8/2015	Lokutu	Typical Concentrations of POME	WB EHS Guidelines Effluent standards
pH	5.83	4.71	4.45		3.4 - 5.2	6 - 9
BOD (mg/ℓ)	9 500				25 000 – 65 000	50
COD (mg/ℓ)	110 000	1 320	660		44 300 – 102 000	
Total Suspended Solids	0.762	3.257	10.306		18 000 – 46 011	50
Dissolved oxygen	0.7	0.6	0.9			
Total nitrogen (mg/ℓ) as N	31.6		17.8			10
Total phosphorus (mg/ℓ)	detected	detected	detected			2
Oils and grease (mg/ℓ)	10.2		25. 939		4 000 - 9 341	10

4 Treatment Options

A literature study was undertaken to identify potential treatment options. The case studies and articles were found to address mainly palm oil mills in Malaysia. Malaysia is currently producing 39% of the world's palm oil production (Natzatul Shima Azmi and Khairul Faezah Md Ynos, 2014).

Due to the high biodegradability of POME, it is a good source of nutrients for microorganisms and can be treated using conventional biological treatment such as anaerobic or facultative digestions (MJ Chin et al, 2013; Natzatul Shima Azmi and Khairul Faezah Md Ynos, 2014).

Treatment options that were discussed included conventional ponding systems, aerobic digestion, anaerobic digestion and physicochemical options. Each of these options is briefly discussed.

4.1 Conventional ponding system

Ponding is a general term which includes waste stabilisation lagoons (ponds) and oxidation ponds. The treatment employs a biological method of treatment which relies on bacteria to breakdown the organic matter into methane, carbon dioxide, hydrogen sulphide and water (Natzatul Shima Azmi and Khairul Faezah Md Ynos, 2014; Wong, 1980).

Literature shows that open ponding system is the most common treatment system used in Malaysia to treat POME (MJ Chin et al, 2013). The system consists of a series of ponds, with each pond having a specific purpose (Natzatul Shima Azmi and Khairul Faezah Md Ynos, 2014). This system may include, but is not necessarily limited to a de-oiling tank, acidification ponds, anaerobic ponds, and facultative or aerobic ponds. The number of ponds will depend on the capacity of the palm oil mill (MJ Chin et al, 2013).

Although ponding systems are widely used throughout Malaysia it is not encouraged due to lack of operational control and long retention time for degradation (MJ Chin et al, 2013).

This biological system requires proper maintenance and monitoring, increasing labour requirements and costs. The microorganisms are also sensitive to the surrounding temperature and pH. The ponds require large areas with a treatment period of 80 to 120 days and enormous quantities of undigested suspended solids (SS) will gradually settle at the bottom and occupy the bulk of the lagoon area. The biological processes produce large volumes of biogas which can be corrosive and result in bad odours. The collection and utilisation of the produced biogas is difficult and results in global warming (Natzatul Shima Azmi and Khairul Faezah Md Ynos, 2014; Wang et al, 2015).

4.2 Aerobic digestion

TY Wu et al, 2015, indicated that a system using an aerobic digestion for POME treatment would be more efficient and the hydraulic retention time (HRT) shorter than that for anaerobic digestion. Aerobic digestion includes the use of fungus in aerated lagoons and oxidation ditches. A continuous rotating biological contactor (RBC) was also used to treat POME. An RBC retains a high biomass and therefore has the capacity to treat concentrated waste water as it tolerates high organic loadings and hydraulic shocks (TY Wu et al, 2015).

The aeration system however, requires large amounts of energy as it is energy intensive. The treated effluent from the aerobic digestion needs to be incorporated into other treatment systems, preferably an anaerobic system prior to discharge (TY Wu et al, 2015).

4.3 Anaerobic digestion or treatment

The literature lists anaerobic treatment as the most suitable method for treating effluent containing high concentrations of organic carbons such as POME. TY Wu, (2010) indicates that anaerobic digestion has been proven to be unique and the most beneficial stabilisation technique as it optimises costs, is environmentally sound and minimises the amount of sludge that needs to be disposed of and it has the ability to produce energy in the form of methane. The proposed anaerobic treatment processes include various types of reactors such as anaerobic suspended growth processes, attached growth anaerobic processes (immobilised cell bioreactors, anaerobic fluidised bed reactors and anaerobic filters), anaerobic sludge blanket processes, membrane separation anaerobic treatment processes and hybrid anaerobic treatment processes (TY Wu, 2010). The use of membrane technology to treat POME is not widely used in the industry due to the high costs for the installation of the membranes and maintenance on the system (Natzatul Shima Azmi and Khairul Faezah Md Ynos, 2014).

4.4 Physico-chemical treatment

The use of physico-chemical treatment has been considered in the past and has been used with various degrees of success. Physio-chemical treatment processes would be particularly useful in applications where the operator wants to combine effluent treatment with the recovery of POME solids. The POME solids can be used for animals or as fertiliser. The physico-chemical treatments may include sedimentation, centrifugation, coagulation, flocculation, flotation, and adsorption. However, TY Wu concluded that although numerous physico-chemical options based on laboratory scale treatment were proposed to treat POME none of these methods could be used as a standalone treatment and it becomes unfeasible and uneconomical.

4.5 Irrigation

Setiadi et al describe how POME could be used to irrigate crops particularly the palm plantations with partially treated POME and that the BOD should be reduced to below 5 000 mg/ℓ before this is practised in Indonesia. They also describe ways in which the POME could be used to irrigate composting organic waste from various sources so that this could be used as fertiliser in the plantations. The utilisation of treated POME as fertiliser increased the FFB production by 13%.

4.6 Overview of treatment options

TY Wu concluded that although various methods of treatment have been proposed in the past the ponding system is still the most common POME treatment system used by more than 85% of the palm oil mills in Malaysia. The reason for this may be due to the availability of land for the construction of ponds; it is more economically viable and has the capacity to tolerate a wider range of organic loading rates (OLR) (TY Wu, 2010).

Amongst all the treatment methods proposed anaerobic digestion is the most advantageous method for POME treatment. It not only treats high concentrations of organic content, but the by-products that are generated as part of the process can be re-used. For example, methane can be harvested and used as an energy source. The anaerobic method is also able to treat the effluent to a satisfactory quality for discharge at lower costs (TY Wu, 2010). Various types of reactor configurations such as closed-tank anaerobic digester, open digester tanks or covered lagoons have been widely used for anaerobiosis (Wang et al). Studies indicated that advanced anaerobic digesters displayed better performance in POME treatment compared to the conventional practices.

However, due to the remoteness of the Feronia Mills, the difficulty in accessing the sites and the availability of materials it appears that the conventional ponding systems will be a viable low-cost treatment option for the Feronia POME. Although this treatment option does have a number of disadvantages it appears to be the most appropriate currently for these remote mills.

The use of the effluent as a fertiliser in conjunction with other organic wastes should be investigated to reduce the environmental burden of the operation and also to increase crop yields.

5 Review of proposals to treat effluent in line with Good International Industry Practise (GIIP)

In June 2014 Feronia management completed a technical review of treatment options for POME. In this report the treatment solutions for each of the three palm oil mills were outlined. A phased approach was proposed:

- During the first phase the BOD will be reduced from 40 000 mg/ℓ to 500 mg/ℓ. This will mainly be achieved through the use of a series of two (2) or four (4) effluent ponds. The first will be an anaerobic pond and the second an aerobic pond;
- During the second phase the BOD levels in the effluent will be reduced from 500 mg/ℓ to 100 mg/ℓ over the period 2016 to 2017; and
- In Phase 3 alternative technologies will be considered to reduce the BOD levels to a maximum of 50 mg/ℓ.

The treatment of the POME at each of the mills is set out in Table 3.

Table 3: Proposed treatment of POME at the various Feronia palm oil mills (Ben Rich/Murray Feddersen)

	Boteka	**Lokutu**	**Yaligimba**
Throughput of tonnes of FFB/hour	5	12	15
Operational hours per week	50	84	80
Existing disposal method for POME	Existing effluent ponds.	Currently POME is discharged directly into the river. Lokutu is surrounded by housing and no area is available for ponds.	POME is discharged into a brick lined channel conveying it several kilometres way to a river.
Proposed disposal treatment	Suitable location for the construction of two effluent treatment ponds, one to provide anaerobic treatment.	Two options were considered: Construction of a packaged treatment plant. Construction of ponds on a piece of flat land which is three kilometres away from the existing site. Four ponds will be required - two ponds for anaerobic and two ponds for aerobic treatment. Final effluent will be pumped back to the river 3 km away.	An area suitable for the construction of effluent ponds has been identified close to the mill. It was proposed that a test pit be dug to determine the water holding capacity of the soil. The soil contains low levels of clay.
Volume of effluent to be treated	312.5 m^3 per week	1 260 m^3 per week	1 500 m^3 per week
Capacity of ponds to allow for 6 weeks retention time	2 000 m^3 in each of the two ponds for a retentions period of 6 weeks in each pond.	3 750 m^3 in each of the four ponds to allow for 3 weeks retention time in each – 15 000m^3 in total. Place to be allowed for expansion of the mill.	4 500 m^3 in each of the four ponds to allow for 3 weeks retention time.

Comments on the ESG Board report proposals:

- Their assumption of 40 000 mg/ℓ BOD seems reasonable when compared to other operations in Malaysia and Indonesia.
- The proposals to allow for 6 weeks retention time at Boteka and 3 weeks at Yaligimba and Lokutu are a lot less than that proposed for similar ponds in Malaysia where they are proposing 80 to 120 day retention periods (11 to 17 weeks). We do not know what the reaction characteristics will be for the Feronia POME, but recommend that additional area and volume be planned for or that the initial ponds are built and then measurements taken to see what the characteristics are before deciding whether additional ponds are needed. The larger retention size will also allow for the build-up of scum and solids in the ponds.
- The design of the retention ponds does not seem to take into account the high rainfall in the region. This may further require greater ponds sizes to achieve the required retention times. The precipitation per annum is 1 725 mm and exceeds evaporation. The design and the construction of the ponds will have to take the rainfall into consideration.
- The approach to treat the effluent in three phases whilst learning about the effluent characteristics seems reasonable.
- The use of conventional ponding systems is conservative and probably correct for the remote locations these mills are situated in. Over time there will be opportunity to collect methane and generate energy or otherwise use the effluent characteristics for greater benefit of the company, but these newer and more sophisticated technologies need to be evaluated over time.
- We cannot comment on the volumes of effluent to be generated in future as we do not know what the production from the various sites will be, but if there are substantial increases in production planned then the ponds proposed will have to be much larger than what has been proposed by ESG and allowance must be made for the area and capital associated with these expansion plans.
- The costs and unit rates proposed by ESG seem reasonable for phase 1, but we cannot comment on the need for a heat exchanger at Lokutu. The total costs may need to rise substantially to achieve the objectives of the treatment if it is found that the retention times need to be longer or the ponds enlarged to cater for increased production.
- It may be possible to use conventional spray irrigation to encourage oxygen transfer and to reduce BOD and COD in the longer term in the final effluent.
- They are worried about the water retention capabilities of the soils at Yaligimba. Allowance may have to be made for importing clay material or synthetic liners if the soils prove permeable.

6 Conclusions

Based on the information obtained through the literature study it appears that the ponds that are proposed are the best available option to treat the POME at each of the plants.

The capacity of the ponds may be too small to get the required retention time, but this aspect needs to be evaluated on site with the characteristics of the POME at each mill. The pond sizes may also need to be expanded to accommodate future production increases and to take into account the high rainfall in the area.

The reaction characteristics of the effluent at each mill should be measured in the ponds when constructed to optimise the sizes of the ponds required and to ensure that there is sufficient retention time.

The company should keep abreast of developments in the field of methane generation and harvesting in future as there could be an opportunity to generate power from the POME. Research into this opportunity should be conducted. Harvesting gas generated from the effluent and its efficient utilisation will also assist in reducing the Green House Gas footprint of the operation.

If the POME and other organic matter can be used as fertiliser it will reduce the environmental burden of the operation and increase crop yields. Methods of doing this should be investigated.

The company may need to allow for increased costs if a lining is needed for the ponds at Yaligimba.

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