CPO Washing (Pos Tank), 3-MCPDE Mitigation System, Operation Experience at Desa Tailisai Palm Oil Mill

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INTRODUCTION

The presence of 3-monochloropropane diol (3-MCPD) esters in refined oil has become food safety issue for the oils and fats industry due to its harmful effects on human (European Food Safety Authority, EFSA, 2018). Among the vegetable oils, refined palm oil is reported to contain the highest level of the esters (EFSA, 2016).

The chemical 3-MCPD and related substances called 3-MCPD esters (3-MCPDE) are food processing contaminants found in some processed foods and vegetable oils, mainly palm oil. 3-MCPD and its esters are formed unintentionally in these foods, in particular during oil refining processes (EFSA 2016). Laboratory studies demonstrated that excessive quantity of these effects could cause long-term adverse effects on the kidney (kidney tubular hyperplasia) and on male fertility (lower sperm production).

The primary precursor for 3-MCPD formation is chloride-containing substances, either organic chlorines, which are naturally present in the soil or oil palm tree, or inorganic chloride primarily from foreign contamination. 3-MCPDE is formed when oil is subjected to extreme heat in the presence of chloride (Hamlet *et al.*, 2011). This happens during physical refining process.

For food safety reason, mandatory 2.5 mg kg^{-1} (ppm) maximum level of 3-MCPDE in refined palm oil are enforced as followed:

i. 1 January 2021: Compliance to EU member countries' requirement.
ii. 1 January 2022: MPOB mandate for national consumption and export.
iii. 1 January 2023: MPOB mandate for both national consumption and export.

For food safety reason, it is important to remove chlorides from CPO to mitigate 3-MCPDE formation in the refining process. The washing can be located either in the palm oil mills or the refineries. There are advantages and disadvantages associated with each location. In this paper, we share our experiences and knowledge on testing of total chloride (TCL) removal in a mill environment. Our learning from MPOB's matching grant intended to assist both the mills and refineries in their process design and technical and commercial evaluation.

Palm oil mill CPO washing system consists of two processes: mixing and separation (*Figure 1*). In the mixing process, treated wash water and CPO are heated prior to mixing. The quantity of washed water used ranged between 5% to 10% of CPO. The mixture is kept in a buffer tank before the separation process. In the separation process, the chloride-laden water is then removed from CPO via POS tank system. The results presented here were obtained from the tank system installed in Desa Talisai Palm Oil Mill. Mechanical separator is another available separation system.

The washed oil exits the POS tank with less than 0.8% and 0.03%, moisture and impurities respectively. The mill vacuum drier is able to reduce the moisture down to below 0.13%. The dried washed oil moisture and impurities combined complied to the commercial contractual limit of 0.25%.

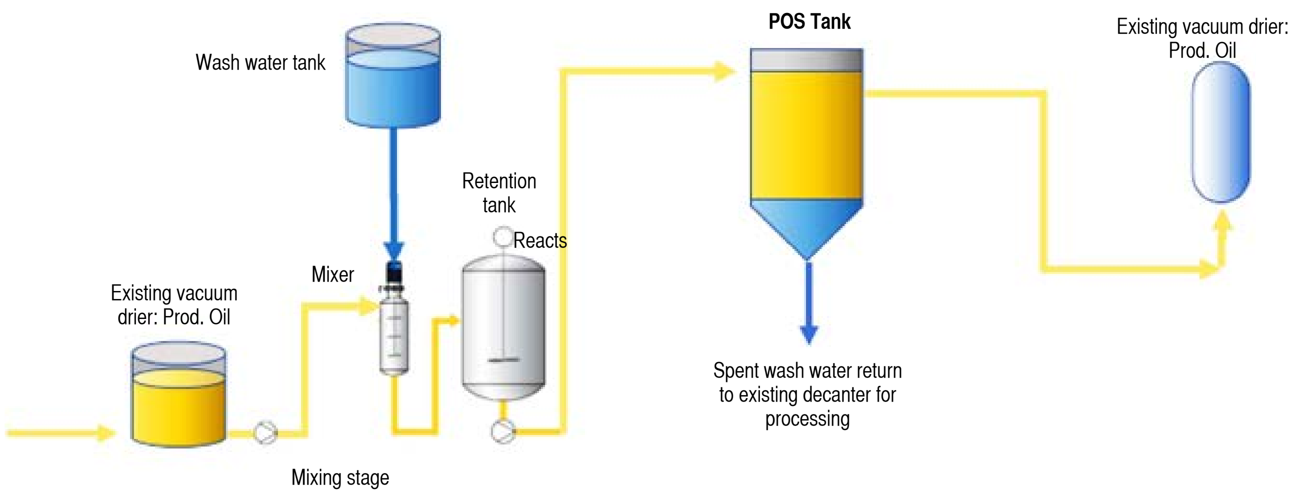

Figure 1. Crude palm oil (CPO) washing process flow.

In the separation process, apart from the washed oil, the spent washed water (SWW) is continuously discharged by POS tank during operation. This SWW is directed to the mill's oil reclaim tank for oil recovery as a last line of defence in oil loss prevention prior to discharging to the effluent treatment ponds.

The tank is emptied by vacuum drying the remaining oils during its periodic cleaning. The balance of the SWW is drained to the oil reclaim tank for recovery and discharge. The emptied tank is then washed, cleaned, and readied for the next process operation. The frequency of cleaning depended on the mill's management practice. In our case, the tank is emptied and cleaned every month.

CPO washing can significantly reduce the inorganic chloride (IOCL) content in CPO. However, due to the chemical properties of the organic chlorine (OCL), washing is not effective for its removal. The process has been demonstrated to effectively remove about 90% of TCL (IOCL) in the mill with the remaining are deemed to be mostly OCL.

PERFORMANCE MONITORING

History of the trial

The CPO washing system was installed in Desa Talisai under the MPOB's matching grant program in 2019. The CPO washing system came with a separator for CPO and water separation. The system operated for six months before being switched to the POS tank to replace the machine.

The objective of the POS tank was to reduce maintenance cost and power consumption associated with the machine and to prevent future capital expenditure for a stand by separator. It was proven to be a success during the industrial trial.

Under the terms of the MPOB matching grant memorandum of agreement, the POS tank was patented by MPOB and IJMEO. The author designed and invented the POS tank. The POS tank was commissioned on 22 October 2019.

Milling process and sources of CPO

The mill's design is conventional with 2.5 mt cage horizontal sterilisers, P15 presses, three phase decanters and empty fruit bunch (EFB) presses.

During production trial, steriliser condensate and EFB liquid were processed in the mill clarification section together with the crude oil from the presses. Thus, the washed CPO consisted of oils from these streams.

Our own estates operations were well controlled and indicated by low FFA of below 3%.

Sampling and Testing of Total Chlorides (TCL)

Each sample was a daily hourly composite sample. In this writeup, the industrial trial period was carried out between October 22, 2019 to February 28, 2021. A total of 357 samples were collected and analysed.

The industrial trial meant for the washing system to operate as part of the milling process.

Samples were analysed by an independent accredited laboratory in Sandakan. The testing procedure was that each sample was tested in duplicate for validation. The average values were reported. The testing methodology was based on ASTM 4929 Procedure B. This said laboratory is listed in MPOB's web site, participating in MPOB's inter laboratory cross checking verification program.

During this trial period, the washing process processed 46 293 mt CPO and 213 704 mt FFB. The process throughput was 12 mt CPO hr^{-1}.

RESULTS AND DISCUSSION

Unwashed CPO characteristics

The TCL content in unwashed CPO ranged from 7 ppm to 130 ppm. Cases with 100 ppm TCL are rare occurrences. However, the common TCL content ranged between 7 ppm to 30 ppm, meaning that CPO washing has to deal with this range much of the time.

The results showed high and low TCL periods in a given year. The low TCL period coincided with high crop production and rainy season, from September till March. The high TCL period coincided with low crop production and dry season from April till August.

The daily composited results demonstrated incidences of significant TCL change from day to day. For example, in December 2020, the TCL content was 14.93 ppm on a given day and 4.68 ppm the next day, and 21.42 ppm the following day. The values fluctuated by a significant magnitude. Although hourly samples were not measured, it is believed that they will fluctuate certainly, except that their magnitude is unknown. The fluctuations and magnitude present challenges in process control. The process is a feedback control operation, meaning that the operation precedes the knowledge of TCL content in CPO feed. We believe the problem could be circumvented by setting the process conditions to deal with high content of TCL in CPO feed. It may not be a perfect solution, but it will help to mitigate the challenges.

TCL removal and TCL in washed oil

During the trial period, the washing process was able to remove on average, 89 % of the TCL. The TCL content in washed CPO was below 2 ppm. The washed oil is transparent and cloudy visually compared to unwashed oil, as shown below (*Figure 2*).

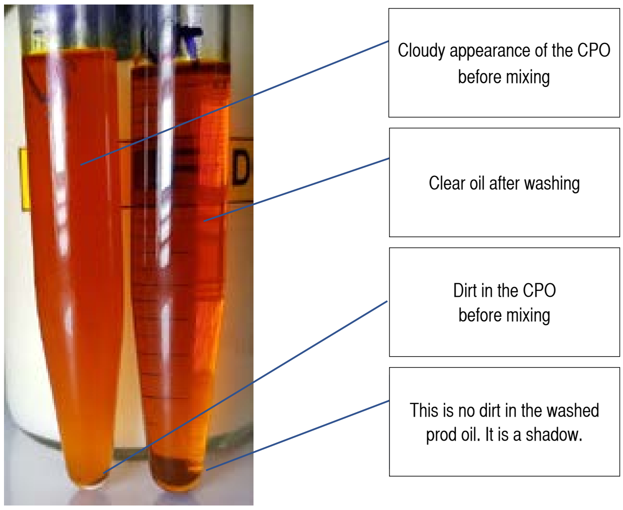

Figure 2. Comparison between washed and unwashed oils

Spent Wash Water (SWW) characteristic

The spent wash water (SWW) is laden with chlorides and other compounds. Only chlorides were measured in the trial. The average TCL content in the SWW was 137 ppm, ranging from 71 ppm to 193 ppm.

The wash water had less than 1 ppm chlorides. During washing, the wash water captured 100 times of its original chloride content. The physical appearance of the SWW is shown in the *Figure 3*.

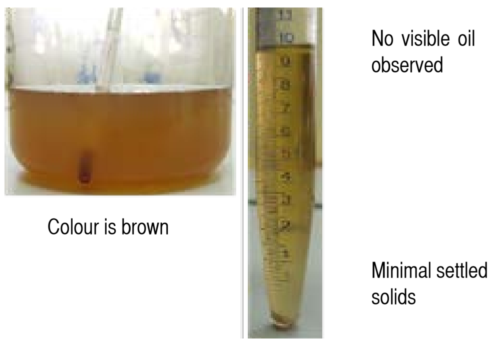

Figure 3. Physical appearance of the spent wash water (SWW).

TABLE 1. SPENT WASH WATER (SWW) POLLUTANT STRENGTH

	Sampling date					
Parameters	06/08/2020	08/08/2020	10/08/2020	11/08/2020	13/08/2020	Averaged
pH Value	4.2@25°C	4.2@25°C	4.0@25°C	4.4@25°C	4.2@25°C	4.2
BOD (3 days @30°C), mg $^{-1}$L	2133	3560	4610	8780	4660	4749
COD, mg $^{-1}$L	5300	6600	8300	17 000	8700	9180
Ammonical Nitrogen (NH3-N), mg $^{-1}$L	6.9	10.5	13.2	28.2	16.9	15
Total Nitrogen, mg $^{-1}$L	61.5	69	71.5	284.1	103.5	118
Oil and Grease, mg $^{-1}$L	113	175.5	346	477.7	477.3	318
Suspended Solids, mg $^{-1}$L	453	363	362	783	295	451
Total Solids, mg $^{-1}$L	3965	4810	6140	13 820	7160	7179

The SWW pollutant strength was measured with 5 samples. Results are shown in *Table 1*. Both BOD and COD levels were significantly lower than the effluent treatment ponds' design limits. The SWW pollutant strength and quantity (5% to 10% of CPO) did not overload the effluent treatment ponds.

It was further observed that the oil and grease content averaged at 318 ppm, or 0.0318%, indicated that oil loss in SWW was low.

Phosphorus and Iron removal

In the course of our trial, apart from chlorides removal, the removal of phosphorous and iron by washing was evaluated. A total of 38 samples were taken and the averaged results are presented the *Table 2*.

The washing process removed phosphorous and iron from the oil by 33% and 32.5% (after POS tank), respectively. The removed compounds were water soluble. The washed oil benefits the refinery though reduction of bleaching earth consumption.

Effects of washing on FFA and DOBI

The effects of washing on the oil quality were evaluated in the trial with results tabulated in Table 3. The delay in process time must be taken into consideration in comparing the results between before wash and production oil. Thus, averaged results were used in this comparison.

The impact of washing using POS tank on both FFA and DOBI is neglectable. The FFA content increased by 2% while DOBI reduced by 1%.

Elimination of purifiers

Prior to CPO washing, the mill uses 2 units of purifier and vacuum dryer to achieve the required moisture and impurity level of 0.25%, in the CPO. An additional benefit of POS tank was the elimination of purifiers. This reduced power, operation cost and future replacement capital expenditure.

The average oil moisture and impurity content of washed oil after POS tank, before vacuum drying, in the trial were 0.63% and 0.02%, respectively (*Table 4*). The purifier design required a maximum 1% moisture and 0.1% impurity in the CPO feed. The purifiers reduced these to 0.5% (moisture) and 0.02% (impurity) prior to feeding to the vacuum dryer. The POS tank proved to be able to achieve the same result with 0.02% impurities at purifier outlet.

TABLE 2. PHOSPHORUS AND FERUM REMOVAL BY WASHING

	Averaged P			Averaged Fe		
	Production oil	Before mixing	After POS tank	Production oil	Before mixing	After POS tank
Average	8.07	11.56	7.75	1.02	1.79	1.21
% Reduction	30.2	0.00	33.0	43.0	0.00	32.5

TABLE 3. EFFECT OF WASHING ON OIL QUALITY

	FFA (%)		
	Before Mixing	Prod oil	(%) increase
12/08/2022	2.28	2.35	3%
13/08/2022	2.04	2.12	4%
14/08/2022	2.10	2.17	3%
15/08/2022	1.91	2.05	7%
18/08/2022	2.76	2.74	-1%
19/08/2022	2.65	2.66	0%
21/08/2022	3.18	3.20	0%
22/08/2022	3.10	3.17	2%
24/08/2022	2.69	3.71	1%
26/08/2022	2.38	2.53	6%
Average	2.51	2.57	2%

	DOBI		
	Before Mixing	Prod oil	(%) Reduce
05/08/2022	2.74	2.72	1%
06/08/2022	2.47	2.42	2%
08/08/2022	2.63	2.68	-2%
10/08/2022	2.85	2.86	0%
11/08/2022	2.72	2.81	-3%
12/08/2022	2.81	2.78	1%
13/08/2022	2.68	2.68	0%
14/08/2022	2.56	2.64	-3%
15/08/2022	2.74	2.63	4%
17/08/2022	2.74	2.57	6%
21/08/2022	2.46	2.34	5%
22/08/2022	2.30	2.45	-7%
24/08/2022	2.67	2.60	3%
25/08/2022	2.54	2.52	1%
Average	2.64	2.62	1%

TABLE 4. MOISTURE AND DIRT

M+I Ex POS Tank			Purifier: Design		Vacuum D: Design	
Trial result period	Parameters	Avg	Inlet: Max	Outlet: Max	Inlet: Max	Outlet: Max
22/10/2019 - 18/11/2019	Moisture	0.63%	1.0%	0.5%	0.5%	0.08%
22/10/2019 - 18/11/2019	Dirt	0.02%	0.1%	0.02%		

The vacuum dryer design required the CPO feed with maximum 0.5% moisture. The machine was able to reduce it to 0.08%. However, our contractual CPO quality of moisture and impurity is 0.25%. There was sufficient buffer to take higher moisture in the feed with 0.63% moisture. The drier was able to take high moisture in the washed oil and still able to dry it to comply to the contractual limit. There were times the moisture in the feed were greater than 0.63% at about 0.8%.

The POS tank is able to make the purifier redundant due to its ability to achieve low moisture and impurity in the washed oil for the vacuum dryer so that it can lower the oil moisture to meet the contractual limit.

The mill has stopped using the purifier since the installation of washing plant with POS tank.

Operation experience and cost

The CPO washing system with POS tank is easy to operate with little training. In comparison with the separator, the POS tank incurred no maintenance cost to date. It does not require electrical power to achieve CPO and water separation and does not need daily cleaning unlike the machine. In our six months of separator operation, wear and tear were observed with wear grooves found in the bowl and its components.

The cost of tank is an advantage as it does not breakdown like a mechanical machine or subjected to concentrated wear and tear. Furthermore, a standby tank is not required, unlike mechanical machine, thereby minimising capital investment. The tank capital cost is lower than that of the machine. Thus, the design objective of the POS tank has been achieved.

Impact of high FFA and low DOBI on TCL removal

It is quite unlikely that high FFA and low DOBI have any impact on TCL removal. Sungai Sabang palm oil mill No. 1, our second washing plant, which was commissioned recently during the rainy and flooding season indicated that TCL could be removed to below 2 ppm, despite the oil containing more than 5% FFA, ranging between 6% to 8%, and DOBI below 2.3.

The second washing plant incorporated with POS tank

In March 2022, the second plant was successfully commissioned and performed as per design specification. The average results are summarised in *Table 5*.

The average results were meant as indication due to limited sampling size.

1. The average TCL content in CPO feed was 20.07 ppm and TCL reduction was 95%. The TCL content in CPO after POS tank was 0.976 ppm.
2. The average FFA and DOBI were 6.25% and 2.22% respectively and TCL removal was achieved.
3. The moisture and dirt content in the CPO feed were 1.04 % and 0.02% respectively. The POS tank reduced the moisture content to 0.46 %. This was good enough to bypass the existing purifiers. After vacuum drier, the production oil moisture content was 0.19%. Subsequently, the mill has stopped using these machines.

The phosphorous and iron content were reduced by 25% and 28% respectively.

These results are similar to the Desa Tailsai palm oil mill's washing plant performance.

TABLE 5. RESULTS FROM SECOND PLANT AT SUNGAI SABANG PALM OIL MILL NO. 1

10 - 26 March 2022 commissioning results	
Day Sampled	14 days
FFB processed (mt)	7171
Total CPO washed (m^3)	1369
CPO washing plant running hours	119

SWW, Spent Wash Water	
Chloride (ppm)	154.94
pH	4.46
TDS	3082.50
Oil Losses % by solvent (wet basis)	0.28

CPO before mixing / CPO feed							
Average TCL (ppm)	20.07	FFA (%)	6.25	Moisture (%)	1.04	Phosphorus (ppm)	18.70
		DOBI	2.22	Impurity (%)	0.02	Iron (ppm)	2.21

CPO after POS tank							
Average TCL (ppm)	0.9765	FFA (%)	6.56	Moisture (%)	0.46	Phosphorus (ppm)	14.10
% CL reduction	95.1%	% reduction in FFA vs before mixing	5%	Impurity (%)	0.02	% reduction P vs before mixing	25%
		DOBI	2.11			Iron (ppm)	1.59
		% reduction in DOBI vs before mixing	5%			% reduction Fe vs before mixing	28%

Production oil							
Average TCL (ppm)	0.9757	FFA (%)	6.48	Moisture (%)	0.19	Phosphorus (ppm)	13.88
% CL reduction	95.1%	% reduction in FFA vs before mixing	4%	Impurity (%)	0.02	% reduction P vs before mixing	26%
		DOBI	2.15			Iron (ppm)	1.37
		% reduction in DOBI vs before mixing	3%			% reduction Fe vs before mixing	38%

Is POS tank applicable in refinery?

The washing process with POS tank system with extension can be applied in the palm oil refinery.

The refinery system will need additional process systems. Dedicated unwashed oil and washed oil storage tanks are needed to support the system. A vacuum drying system is needed to lower the washed oil moisture level to 0.25%. The refinery's waste water treatment plant needs to be reviewed for its existing treatment capability to handle the waste water generated by the washing plant. A washing plant recycling system is needed to return the oil in the system back to the feed tank. This process is patent pending.

CONCLUSIONS AND WAY FORWARD

At the time of writing, the mills and refineries are finalising the most suited location to carry out the CPO washing. MPOB's mandate is in place for the compliance of 3-MCPDE of 2.5 ppm (mg kg^{-1}) in refined oil products from 1 of January 2023 for both national consumption and export. Food safety is the paramount importance, followed by upholding our Malaysian palm oil reputation.

On the world's stage, Malaysia's success in achieving 3-MCPDE quality parameter on refined oils means that the buying countries will exert pressure on other palm oil producing countries to comply. It will give our country an edge over others in supplying better quality products. Perhaps, it may even command monetary premium.

On the local front, the palm oil industry will settle on the location of CPO washing eventually. Some mills may choose to wash and some refineries will carry out the washing. Refineries will certainly establish TCL limit in CPO just like FFA, M+I, and DOBI, which is likely to be as followed:

1. Washed CPO: 2 ppm of TCL or less.
2. Unwashed CPO: TCL value is yet to be determined.

For mills who choose not to wash, the unwashed oil TCL limit will be critical. It will be a fixed limit like 5% FFA and below. Assuming that, these mills experience fluctuation like in the trial, penalty may be incurred for failing to meet the specification if there is no effective means of quality control. It is advisable for the mills to verify occurrence of the fluctuation and its magnitude.

IOCL will convert to OCL and washing cannot remove OCL. If OCL becomes difficult to manage, it is possible that refineries may impose a limit of OCL to fortify their quality control and assurance.

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