Revolutionizing Palm Oil Wastewater Treatment: Hydroleap's Electrochemical Solution for Mills and Refineries

Hydroleap

Forward

The palm oil industry faces significant environmental challenges, particularly in wastewater management. These challenges span both palm oil mills and refineries, where large volumes of wastewater are generated during crude palm oil (CPO) extraction and washing processes. This report demonstrates how Hydroleap's innovative electrochemical technologies offer sustainable, efficient, and cost-effective solutions for both palm oil mill effluent (POME) and CPO washing wastewater treatment, helping producers meet regulatory requirements while enhancing their environmental performance and operational efficiency.

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Global Palm Oil Industry Overview and APAC Context

Palm oil is the most widely produced and consumed vegetable oil in the world, accounting for approximately 30% of global vegetable oil output. Its versatility across food, personal care, and biofuel sectors has driven steady global demand. However, this economic significance comes with environmental challenges - chief among them, the generation of large volumes of high-strength wastewater from various stages of processing.

This wastewater is broadly categorized into two streams:

- **P**alm Oil Mill Effluent (POME) generated during the oil extraction process at mills
- CPO washing wastewater generated during the refining of crude palm oil (CPO) at refineries

Both streams are highly polluting and require tailored treatment strategies.

APAC Dominance in Palm Oil Production

The palm oil supply chain is highly concentrated in Southeast Asia. Indonesia and Malaysia together produce over 84% of the world's crude palm oil (CPO)—with Indonesia alone contributing ~46 million metric tons and Malaysia ~18 million tons annually. Other APAC countries like Thailand and the Philippines have smaller but growing industries, while Singapore and Australia are key players in trade, technology, and regulation.

Due to this concentration, the region also bears the brunt of the environmental impacts, particularly from wastewater management and carbon emissions. At the mill stage, a typical facility generates 2.5 to 3 tons of POME for every ton of CPO*. At the refinery stage, CPO washing generates additional wastewater that is often overlooked, yet poses equally significant challenges.

Source: Dominic and Baidurah, 2022, "Recent developments in biological processing technology for palm oil mill effluent treatment - A review"

POME and CPO Wastewater Characteristics & Environmental Impact

Palm oil production generates significant volumes of high-strength wastewater at both mill and refinery stages. The two primary waste streams, POME and CPO Washing Wastewater, exhibit different characteristics, yet both pose serious environmental risks if untreated.

- POME originates at the mill during the extraction of CPO and is highly loaded with organic matter, solids, and oil.
- CPO Washing Wastewater is generated at the refinery stage, typically during degumming, neutralization, and washing processes. Though generally lower in solids than POME, it still contains high levels of residual oil, COD/BOD, surfactants, and color.

Parameter	Typical Range (Raw POME)	CPO Washing Wastewater Effluent (Refinery-Level
Biological Oxygen Demand (BOD)	25,000 – 70,000 mg/L	1000-2500 mg/L
Chemical Oxygen Demand (COD)	50,000 – 100,000+ mg/L	2000-5000 mg/L
Total Suspended Solids (TSS)	15,000 – 50,000 mg/L	500-1500 mg/L
Oil & Grease	2,000 – 5,000 mg/L	200-1000 mg/L
pH	4.0 – 5.5	4 – 6
Various Pollutants (Nitrogen, Phosphorus, Potassium)	Present in moderate levels	Nitrogen, Ammonia, Phosphorus, Chloride, Sulfate

This high pollutant load, whether from mills or refineries, stems from organic residues (cellulose, sugars, lipids), acidic pH, and oil contaminants, making palm oil wastewater one of the most challenging agro-industrial wastewaters to manage.

The environmental impacts of improperly treated POME include:

1 Water Pollution

- High BOD and COD levels deplete oxygen in receiving water bodies, leading to fish kills and ecological disruption
- COD levels downstream from three mills averaged 4,600 mg/L (national limit: 100 mg/L)
- BOD averaged 2,300 mg/L (national limit: 20 mg/L)
- Typical wastewater volume generated from Mill and Refinaries
- Palm oil mills typically generate 2.5–3.5 m^3 of wastewater per tonne of crude palm oil (CPO) produced.
- Palm oil refineries typically generate 0.2–0.5 m^3 of wastewater per tonne of CPO refined
- High turbidity and suspended solids significantly impacted aquatic ecosystems

Aziz, N., et al. (2024). Assessment of Palm Oil Mill Effluent (POME) impacts on surface water quality in Johor, Malaysia. Environmental Pollution & Management.

2 Soil Contamination

- Land application of untreated POME leads to soil clogging, acidification, and plant die-off
- Infiltration rate dropped from 21.3 mm/hr (baseline) to 6.8 mm/hr after 3 years of raw POME application.
- After multiple growing seasons, field plots receiving untreated POME exhibited poor infiltration rates and surface water pooling, especially during the wet season.
- Nitrate levels near POME application fields rose to 47 mg/L (above WHO limit of 50 mg/L)
- Soil porosity reduced by 18%, primarily in loamy and clay-loam soils.
- Soil acidification observed with pH decline from 6.5 to 5.1

Santoso, R., et al. (2023). Long-term effects of raw POME land application on soil and groundwater quality in Central Kalimantan. Journal of Environmental Sciences.

The environmental impacts of improperly treated POME include:

3 Greenhouse Gas Emissions

- Anaerobic degradation in open ponds releases significant volumes of methane (CH_4), a potent GHG—contributing heavily to the palm oil industry's carbon footprint
- Methane emissions from uncovered anaerobic ponds estimated at 22.8 kg CH_4/ton fresh fruit bunch (FFB)
- Equivalent to 570 kg CO_2-eq/ton FFB
- Biogas capture systems can reduce emissions by over 85%

Putra, H., & Lim, J. (2024). Methane emissions from open POME treatment ponds in Sumatra: Quantification and mitigation potential. Renewable & Sustainable Energy Reviews.

4 Odor and Community Impact

- Accumulation of volatile fatty acids and sulfides in untreated POME generates strong odors, affecting nearby communities
- Untreated POME, especially in open lagoons, emits high levels of foul-smelling gases such as hydrogen sulfide (H_2S concentrations up to 100 ppm) and volatile fatty acids (VFAs), which are primary odor contributors.
- Exposure to these odors has been linked to health issues, with nearby residents reporting respiratory irritation in 70% of cases, along with headaches and nausea.
- Persistent odors cause daily nuisance, reducing quality of life and leading to community complaints in over 80% of villages adjacent to mills.

Tan, Y.H., & Abdul Aziz, A.R. (2014). Emission of malodorous gases from palm oil mill effluent (POME) treatment in Malaysia: A review. Environmental Technology Reviews

Given these risks, effective treatment of POME and CPO washing wastewater is essential—not only to protect the environment but also to comply with increasingly stringent national and regional regulations. The following section outlines key discharge standards across Southeast Asia, with a focus on Malaysia and Indonesia, where palm oil production is most concentrated.

Regulatory Landscape in APAC

Palm oil producers in Southeast Asia, particularly in Malaysia and Indonesia, must now comply with strict environmental standards regulating the discharge of pollutants such as BOD, COD, TSS, and oil & grease—parameters that are especially relevant given the high organic load of untreated POME.

Category	Malaysia (DOE – Standard A / B)	Indonesia(MOEF)
BOD Limit	A: ≤ 20 mg/L B: ≤ 50 mg/L	≤ 100 mg/L, often ≤ 50 mg/L
COD Limit	A: ≤ 80 mg/L B: ≤ 200 mg/L	≤ 350 mg/L
TSS Limit	A: ≤ 50 mg/L B: ≤ 100 mg/L	≤ 150 mg/L
Oil & Grease	A: ≤ 5 mg/L B: ≤ 10 mg/L	≤ 25 mg/L
pH	6.0 – 9.0	6.0 – 9.0
Sustainability Scheme	RSPO (global, voluntary)	ISPO (Indonesia-only, mandatory)
GHG Reduction	Methane tracking required under RSPO	Methane reduction encouraged regionally

In parallel, local communities, global buyers, and ESG-focused investors are demanding cleaner, more responsible operations, pushing producers to adopt compact, compliant, and chemical-free wastewater solutions.

Current Treatment Methods and Limitations in Palm Oil Industry

Palm oil mills commonly rely on conventional systems such as cooling ponds, sedimentation tanks, and anaerobic lagoons.

While these are low-cost and familiar, they face serious limitations:

- **Land-Intensive:** Conventional lagoon systems occupy 4–5 hectares per mill, consuming valuable operational space
- **Slow Processing:** Typical retention times of 60–120 days hinder scalability and responsiveness to fluctuating loads
- **Inconsistent Output:** Output often fails to meet stricter BOD (e.g., <20 mg/L) or color standards without tertiary polishing
- **Methane Emissions:** Open anaerobic system release high levels of CH_4, a GHG more potent than CO2
- **High Sludge and Chemical Use:** Chemical coagulation/DAF units used for polishing generate excess sludge and incur recurring chemical costs
- **Poor Final Polishing:** Most systems lack effective disinfection or decolorization, making reuse or sensitive discharge unfeasible

At the refinery level, CPO washing wastewater is typically treated using physical-chemical methods such as oil-water separators, neutralization tanks, or conventional dissolved air flotation (DAF).

However, these too face limitations:

- **Limited Pollutant Removal:** Conventional methods often fall short in removing oil & grease, surfactants, and color compounds
- **Space and Scalability Challenges:** As with mill operations, footprint and modular scalability remain key concerns
- **Regulatory Gaps:** Inconsistent discharge quality makes compliance with modern discharge standards difficult, especially near urban or coastal zones

Opportunities for Sustainable Wastewater Treatment

To address rising environmental standards and land constraints, producers are shifting toward compact, modular, and chemical-free systems that offer:

Faster Treatment Cycles

Electrochemical technologies reduce retention time from months to hours

Small Footprint

Skid-mounted systems free up land and simplify retrofitting

Compliance Readiness

Meets BOD, COD, and color limits across Malaysia, Indonesia, and RSPO/ISPO frameworks

GHG Reduction

Avoids methane emissions from anaerobic digestion

OPEX Savings

Cuts chemical and sludge handling costs

Water Reuse Potential

High-quality effluent enables irrigation or internal recycling

These emerging technologies enable palm oil producers – at both mill and refinery levels – to move beyond compliance and toward sustainable, resilient operations.

Hydroleap's Electrochemical Solution for Palm Oil Wastewater Treatment

Palm oil production generates wastewater at two key stages of the value chain:

1

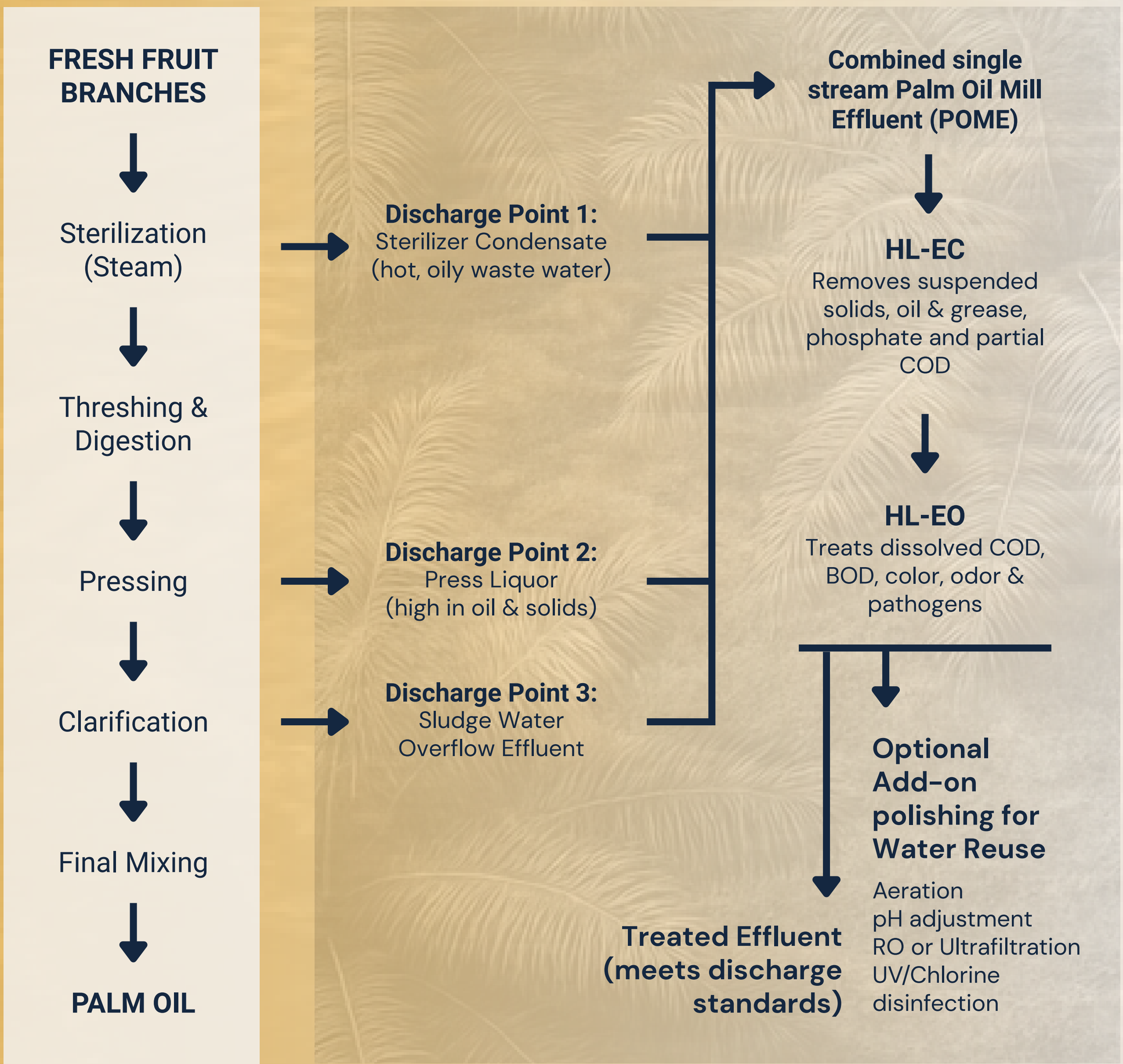
Mills (POME – Palm Oil Mill Effluent)

Palm oil mills generate POME at multiple stages of the production line.

Key discharge points include:

- Sterilizer condensate from steaming fresh fruit bunches
- Press liquor from oil extraction
- Sludge water from clarification and separation

These wastewater streams are collected and mixed into one combined raw POME stream, which is then sent for treatment.



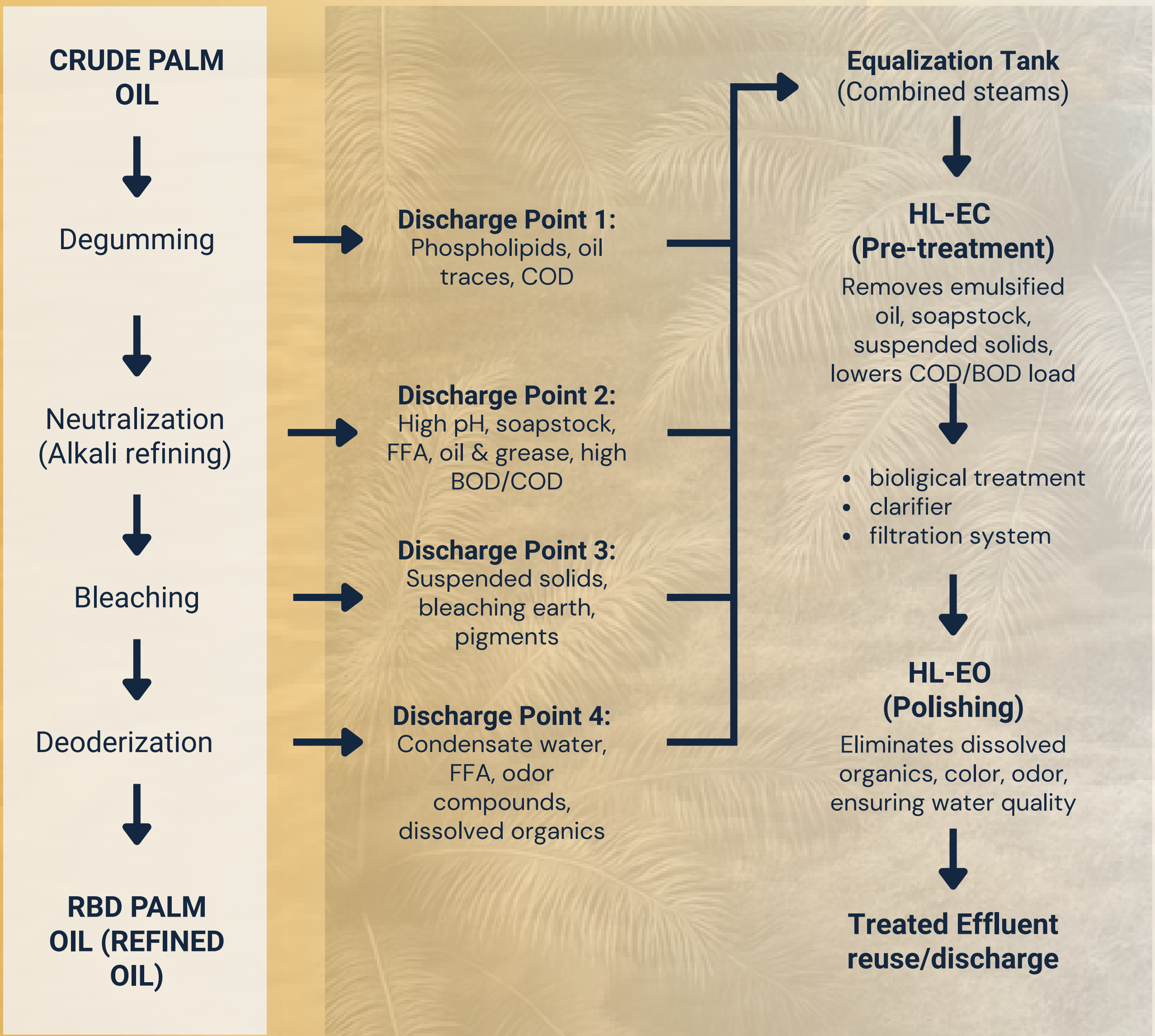
Palm Oil Mill Effluent (POME) process flow with Hydroleap integration

2

Refineries
(CPO Washing Wastewater)

Crude palm oil (CPO) refineries produce additional wastewater streams, particularly during degumming, neutralization, washing, and bleaching.

These contain surfactants, color compounds, high COD/BOD loads, and dissolved organics, and can be effectively treated using similar electrochemical methods.



CPO Washing Wastewater process flow with Hydroleap integration

*Side stream option, if soapstock/alkaline stream is extremely strong, neutralize/demulsify as a side treatment before sending Equalization tank

The Hydroleap Two-Stage Solution

Hydroleap's electrochemical system replaces conventional biological and chemical treatments:

1 HL-EC (Electrocoagulation): Removes suspended solids, oil & grease, phosphates, and lowers COD/BOD load

2 **HL-EO (Electrooxidation):** Polishes effluent by eliminating recalcitrant COD, BOD, color, odor, and pathogens

Together, they offer a compact, chemical-free, and fully automated solution that meets stringent discharge standards or enables water reuse.

Hydroleap's EC + EO system produces high-quality effluent that complies with national discharge regulations. For facilities, whether mills or refineries—aiming for internal water reuse (e.g., boiler feed, wash water), optional polishing (aeration, RO/UF, UV or chlorine disinfection) may be added depending on reuse standards.

Hydroleap's Electrochemical Solution for POME Treatment

1 HL-EC (Electrocoagulation) Primary Treatment

HL-EC uses low-voltage electricity and aluminum electrodes to destabilize suspended solids and emulsified oil, forming flocs that are removed downstream. This eliminates the need for chemical coagulants and reduces sludge generation compared to conventional chemical treatment.

Key Capabilities

01

Up to 90% of TSS, and up to 95% of oil & grease removal

02

Removes up to 90% phosphate and certain heavy metals

03

Up to 90% of TSS, and up to 95% of oil & grease removal

04

No external chemicals required — only durable aluminum electrodes

05

Applicable to both mill (POME) and refinery (CPO washing wastewater) streams, lowering chemical costs and simplifying compliance

2 HL-EO (Electrooxidation) Secondary/Polishing Treatment

HL-EO applies voltage across catalytic electrodes mixed metal oxide anodes to generate reactive oxidants (hydroxyl radicals, free chlorine). These destroy recalcitrant organics, color-causing compounds, and pathogens.

Key Capabilities

01
>90% COD and BOD reduction in less than 15minutes

02
Complete color and odor removal

03
Built-in pathogen disinfection — no chlorine dosing needed

04
Final effluent is suitable for discharge or reuse

05
Delivered as a skid-mounted, scalable, and plug-and-play system

By integrating HL-EO, palm oil producers, at both mill and refinery levels, can transition from outdated biological or chemical polishing systems to modern, compliant operations with minimal operational disruption.

Integrated EC-EO System

List of Benefits

Footprint

Compact, containerized; can replace ponds

Maintenance

~1.5–2.1 kWh/m³ for combined EC+EO

Modularity

Scalable 1–20 m³/hr modules; easy retrofit

Sludge

Minimal, easy-to-handle sludge (lower than alum-based)

Automation

Fully automated with remote monitoring options

Energy Use

Electrode cleaning every 3–6 months; no daily dosing

Chemicals

100% chemical-free (no coagulants or biocides)

What sets **us** apart?

Hydroleap's HL-EC and HL-EO systems provide a transformational shift in how palm oil producers manage wastewater, across both mills (POME) and refineries (CPO washing wastewater). Compared to conventional treatment systems, this electrochemical approach offers distinct environmental, operational, and financial advantages:

01
Environmental Benefits

- **No chemicals:** Eliminates alum, polymers, chlorine, and their environmental risks
- **Up to 99% reduction** in TSS and oil & grease; >90% COD and BOD reduction
- **Color and odor removal** via oxidative degradation of lignocellulosic organics
- **Significantly reduced methane emissions:** Avoids anaerobic ponding altogether

02
Operational Efficiency

- **Compact footprint:** Replaces multi-hectare pond systems with container-sized units
- **Short retention time:** EC ~5–10 mins; EO ~5–15 mins vs. 60–120 days in ponds
- **Fully automated:** Minimal operator input, remote monitoring available
- **Stable performance:** Consistent results even with fluctuating wastewater loads
- **Quick deployment:** Plug-and-play configuration for retrofits or new mill designs

03
Economic Advantages

- **Lower OPEX:** No recurring chemical costs and reduced sludge handling expenses
- **Energy-efficient:** EC+EO system operates at ~1.5–2.1 kWh/m^3
- **High ROI:** Payback period of 22–26 months (based on 400 m^3/day in past case)
- **Water reuse-ready:** Effluent can be recycled for mill operations or refinery utilities (e.g., boiler feed, washing, or irrigation)

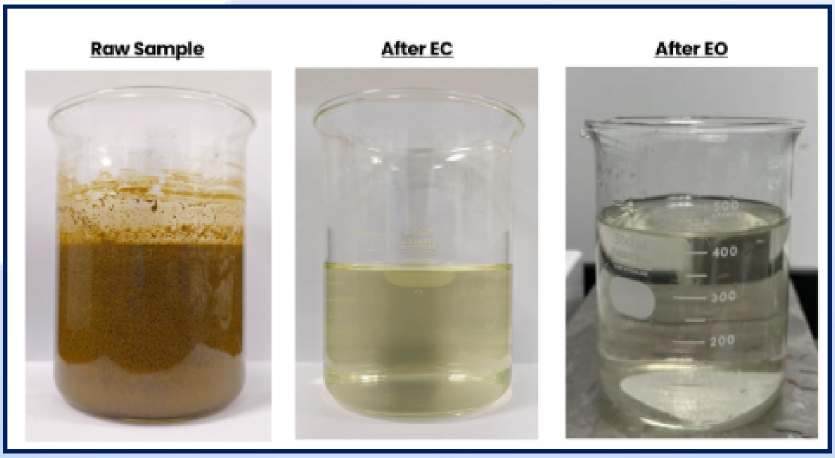
Performance Validation:
Hydroleap's Technology in Action

Hydroleap's electrochemical treatment system has been validated using real-world palm oil wastewater samples under actual site conditions. The following example demonstrates the performance of the system in treating raw **Palm Oil Mill Effluent (POME):

**While this validation example highlights performance on mill effluent (POME), Hydroleap's EC–EO system is equally applicable to refinery wastewater streams, where similar pollutant loads (oil & grease, COD, color, surfactants) are present.

Parameter	Raw POME	After HL-EC+EO	Removal Efficiency
COD (mg/L)	7000-8000	500-600	92%
TSS (mg/L)	1500-1600	>10	>99%
pH	5.6–5.7	~6.5–7.0	Neutralized (no pH dosing)
Color	Brown slurry	Light yellow	Fully decolorized
BOD	2800-3200	20-100 mg/L	>90% (expected)

Source: validation of untreated raw POME, tested under native conditions



Raw wastewater samples were treated using Hydroleap's two-stage system (HL-EC followed by HL-EO) under actual site conditions, without chemical pre-treatment or pH adjustment.

Performance Validation: Hydroleap's Technology in Action

Validated Process Settings

10 mins
EC Duration

7.5–10 mA/cm²
EC Current Density

15 mins
EO Duration

Not Required
pH Adjustment

Outcome

Effective COD, TSS, and color removal without chemical pre-treatment

System Performance Snapshot
(400 m³/day design basis)

~20-30 mins (EC + EO)
Total treatment time

Every 8-12 months
Maintenance: Electrode Cleaning

Drier, Minimal, Easier to handle
as compared to sludge from chemical coagulation

~2.0 kWh/m³
Energy consumption

Outcome

The treated effluent was visibly decolorized, significantly cleaner than DAF(Dissolved Air Flotation)-treated discharge, and met local discharge thresholds.

The process achieved full removal of solids and oil, and significant reductions in organic load, offering a realistic, chemical-free alternative to conventional biological treatment and chemical treatments — with potential for reuse when combined with polishing (e.g., RO or UV).

Competitive Landscape:
Hydroleap POME vs. Traditional Systems

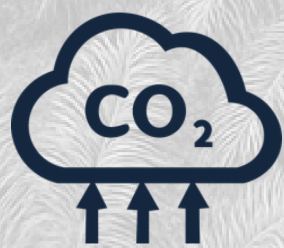
Palm oil producers commonly rely on:

1. Biological treatment methods such as anaerobic lagoons and aerobic/facultative ponds, which require long retention times (60–120 days), large land areas, and often emit methane as a byproduct.

2. Chemical coagulation + DAF units, which use alum, lime, and polymers to remove solids and oil, but generate large volumes of chemical sludge

These legacy methods are familiar but come with trade-offs:

Slow Processing



High Emissions

Recurring Chemical Costs

Difficulty meeting stricter BOD and color limits

This is where Hydroleap steps in:

Hydroleap replaces this outdated model with a compact, fully automated, chemical-free alternative - capable of treating wastewater from both mills and refineries in under an hour and meeting even the toughest discharge standards.

Competitive Landscape: Hydroleap POME vs. Alternative Solutions

Hydroleap's EC and EO technologies provide a compact, chemical-free alternative to traditional wastewater treatment in both palm oil mills (POME) and refineries (CPO washing). The table below compares Hydroleap's solution against the most common industry methods.

The table below compares Hydroleap's solution against the most common industry methods.

Criteria	Biological Treatment (e.g., Anaerobic /Aerobic Ponds)	Chemical Coagulation + DAF	Hydroleap EC + EO
BOD/COD Removal	Moderate (BOD <100–200 mg/L)	High with polishing	**High (>90%) – Consistent**
TSS & O&G Removal	Moderate	High	**>99% – Without chemicals**
Color Removal	Poor	Partial	Excellent (oxidation-based)
Disinfection	None	Requires chlorine	**Integrated via EO**
Treatment Time	**60–120 days**	1–2 days	~1 hour (combined EC + EO)
Chemical Usage	None	High (alum, lime, chlorine)	**None (electrodes only)**
Sludge Volume	High (organic + chemical)	High	**Low – Dry, stable sludge**
Land Requirement	Very high (multi-hectare ponds)	Medium	**Low – Skid/container-based**
OPEX	Low (but high maintenance risk)	High	**Low – energy only**
GHG Emissions	**High (methane)**	Medium	**Very low – no methane**
Automation	Low	Medium	**High – Fully automated**

Hydroleap offers a sustainable, high-performance alternative to traditional and chemical-based systems. It eliminates chemical dependencies, reduces land and energy use, and delivers predictable results that help palm oil producers meet evolving regulatory and ESG standards.

Regulatory Landscape in APAC

Palm oil producers in Southeast Asia, particularly in Malaysia and Indonesia, must now comply with strict environmental standards regulating the discharge of pollutants such as BOD, COD, TSS, and oil & grease—parameters that are especially relevant given the high organic load of untreated POME.

Category	Malaysia (DOE – Standard A / B)	Indonesia(MOEF)
BOD Limit	A: ≤ 20 mg/L B: ≤ 50 mg/L	≤ 100 mg/L, often ≤ 50 mg/L
COD Limit	A: ≤ 80 mg/L B: ≤ 200 mg/L	≤ 350 mg/L
TSS Limit	A: ≤ 50 mg/L B: ≤ 100 mg/L	≤ 150 mg/L
Oil & Grease	A: ≤ 5 mg/L B: ≤ 10 mg/L	≤ 25 mg/L
pH	6.0 – 9.0	6.0 – 9.0
Sustainability Scheme	RSPO (global, voluntary)	ISPO (Indonesia-only, mandatory)
GHG Reduction	Methane tracking required under RSPO	Methane reduction encouraged regionally

In parallel, local communities, global buyers, and ESG-focused investors are demanding cleaner, more responsible operations, pushing mills to adopt compact, compliant, and chemical-free wastewater solutions.

Implementation and Integration

Hydroleap's EC and EO systems are designed to fit easily into existing palm oil operations without requiring major infrastructure changes or downtime.

Easy to Retrofit or Deploy :
Our skid-mounted modules are plug-and-play:

- No deep civil works or large tanks
- Connects directly to existing equalization tanks or DAF units
- Can be installed in days, not months

Minimal Disruption to Operations:

- Installation can be staged during regular maintenance
- Systems run independently, so existing ponds or clarifiers can remain as backup
- No need to stop mill operations during commissioning

Scalable for Any Facility Size :

- Whether treating 100 or 1,000 m^3/day, capacity can be scaled by adding modules. Our systems support phased rollouts and future expansion without overbuilding from day one.

Integration Scenarios

Mill Type	Integration Approach
New mill	EC + EO system installed as primary treatment
Pond retrofit	Replace or reduce anaerobic ponds
DAF enhancement	Replace chemical coagulation + disinfection
Expansion projects	Add modular EC + EO to boost existing capacity
Refinery retrofit	Integrate EC + EO after neutralization/washing for COD, color, and surfactant removal

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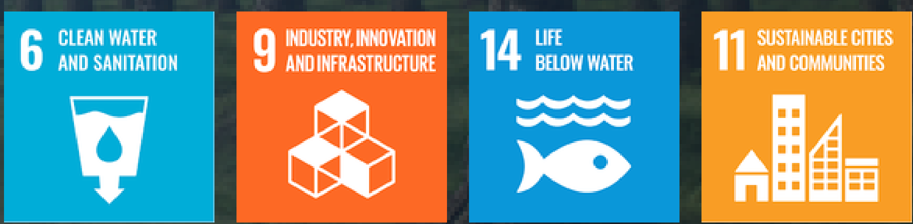
About Hydroleap

Hydroleap is a leading technology company headquartered in Singapore specializing in advanced water and wastewater treatment solutions. Equipped with patented electrochemical technologies and over 8+ years of R&D, we have a proven track record of delivering innovative solutions to world-class customers across various industries, including data centers, manufacturing, and desalination. Hydroleap is backed by various institutional investors such as Antares Ventures, Sinarmas Group, Economic Development Board of Singapore (EDB), SEEDs Capital, Mitsubishi Electric, UntroD Capital, State Government of Victoria, Wavemaker Partners, 500 Global and SparkLabs Cultiv8.

Hydroleap is proud to align its innovations with the United Nations Sustainable Development Goals, particularly SDG 6 (Clean Water and Sanitation), SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 14 (Life Below Water).



Hydroleap's mission

To revolutionize cooling systems by providing sustainable, chemical-free, and energy-efficient solutions. We are committed to supporting data centers in achieving their sustainability and climate goals through our proprietary electrooxidation technology (HL-EO-CT), which significantly reduces water usage, energy consumption, and chemical usage.

Hydroleap

Partner with us to **revolutionize** your water and cooling systems for a more sustainable future.

Contact Information

For more information or to discuss how Hydroleap can support your cooling tower or water treatment needs, please contact us:

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