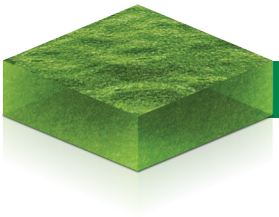




WHITE PAPER

## Electro Water Separation

# EWS for Algae: A Superior Algae Harvesting Process

## Background

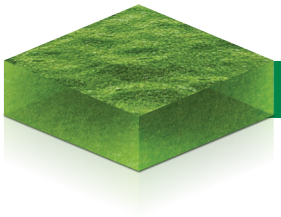
Current equipment used to mechanically harvest algae cells from growth water has been beset by problems. Centrifugal or vacuum belt systems apply force to separate the algae, resulting in fracture of fragile algae cell walls. The problem is further exacerbated by the need to add toxic chemicals to kill bacteria which attack and rapidly destroy the damaged algae cells. The result has been drastically reduced shelf life of harvested algae which has seriously hampered the expected development of this new biofuel source.

This serious problem has been successfully addressed by OriginClear's Electro Water Separation™ (EWS) technology which embodies a non-mechanical, non-chemical method to harvest algae which has none of these limitations and produces intact algae cells in a reduced bacteria concentration and does it with very low energy usage.

The EWS Algae is a continuous flow through electro-catalytic process that harvests algae from growth medium. The process has been found to offer some key commercial advantages...

EWSfor Algae is a continuous flow through electro-catalytic process that harvests algae from growth medium. The process has been found to offer some key commercial advantages:

- Harvests algae cells out of the growth medium intact, thus greatly increasing shelf life.
- Greatly reduces bacteria load on harvested biomass by rupturing bacteria cells and killing the bacteria.
- Brings under control two of the major impediments to steady exponential growth of algae; "shadowing effect" and bacterial infestation.






## Abstract

Separation of microscopic algal cells from a growth medium while destroying bacteria without affecting green algae, diatom or cyanobacteria is done utilizing OriginClear's EWS Algae. The process also results in decontamination of the effluent water which is now re-injected as clean water.

Reducing shadowing by lowered density as mature biomass is harvested and destruction of bacterial cells allows younger cells to compete and avoids crashing of the algae culture.

This method allows for a continuous process as two of the major impediments to exponential growth – shadowing and bacterial infestation – are now brought under control.


The EWS Algae system kills bacteria without harming algae by inducing reactive ionic species during the electro-catalytic process.

## Introduction

Algae growth is dependent on three factors:

1. Light accessibility.
2. Nutrient availability.
3. Microbiological attacks by adverse organisms (such as bacteria and fungi).

Anything that affects these three factors can result in increased competition for resources and lower growth rates for the algae.

Light limitation at high biomass occurs when the cells absorb most of the incoming irradiation and individual cells shade each other.

Organisms such as bacteria compete for nutrients and can also attack algae cells, thus inhibiting exponential growth and sometimes causing a complete crash of algae culture.

## Commercial Advantages of EWS Algae Technology

The EWS Algae system kills bacteria without harming algae by inducing reactive ionic species during the electro-catalytic process.

These reactive ionic species remove electrons from bacterial membranes which leads the membrane to become destabilized and leaky. Destroying the integrity of the cell walls leads to rapid death of bacteria.

Microalgal cell walls are composed of cellulose, which protects them from losing electrons so they do not destabilize. The entire process does not use any chemicals.

By removal of bacteria, EWS Algae technology reduces competition for nutrients and attacks on algal cells, which allows algae to continue in its ideal exponential growth phase.

## Comparing OriginClear EWS Algae with Existing Commercial Systems

It is critical to solve the issues confronting algae growers by supplying a device that can alleviate shadowing, destroy competing bacterial load and deliver a clean intact biomass that has a greatly increased shelf life and can be processed into food or fuel. The EWS Algae continuous process system does this and wins hands down over current batch systems.

EWS Algae can increase growth rates and deliver a cleaner product that has longer shelf life than conventional extraction methods which are generally centrifuge or vacuum belt systems which tend to fracture the fragile algae cell walls.

These other systems extract biomass, but do not provide decontamination of the water, let alone the biomass and are not usually utilized on a continuous basis.

EWS Algae has a surprisingly low energy cost, so the advantages of its continuous operation does not add a significant cost factor.

EWS Algae can increase growth rates and deliver a cleaner product that has longer shelf life than conventional extraction methods which are generally centrifuge or vacuum belt systems which tend to fracture the fragile algae cell walls.

EWS Algae is highly adaptable to existing conditions and its operating parameters can be tuned to harvest and disinfected water.

## Specifying Downstream Systems for End-User Applications

EWS Algae produces a slurry, or concentrate, with roughly 5% solids content. The microalgae is generally left whole and viable.

On request, OriginClear will specify additional downstream devices to achieve greater concentration and also process the algae for beneficial products, such as:

- Conveyor belts
- Drying beaches
- Pelletizers
- Centrifuges
- Membrane separators
- Hexane-based lipid extraction systems
- Supercritical CO2 extraction systems

EWS Algae is, therefore, a complement to existing harvesting, drying and extraction systems.

## Added Benefits of EWS Algae as a Core Growth System Component

An added benefit of the EWS Algae system is an aeration component of the processed water through the use of a gaseous hydrogen/oxygen flotation device and furthermore, this oxygen and hydrogen mix, generated by electro-catalytic materials, can be enhanced by certain mineral oxides such as Fe[1] which can re-mineralize depleted stock.

Customization of this continuous batch process can include multiple system modifications, where the collection point also becomes the injection point for nutrient delivery and introduction of new stock, such as might be required by modified algae gene species.

While the volume of extracted material can vary, a recommended value should be set at between 20 and 30% of the total matrix on a daily harvest. Total water usage drops as all of the water can now be re-used and only supplemental (top-off) water is required.

The EWS Algae system envisions a central point where all of the activity of collection and feeding takes place on even the largest of farms or photo bio-reactor (PBR) locations. This is only made possible by the bacteria free nature of the EWS Algae harvest and the re-introduction of bacteria free and mineralized water to the growth area.

The relatively low operational costs of this new harvesting method are an added benefit, as the cost of operation is substantially less than centrifuging and can be run in some cases by solar power or other alternative forms of energy.

## Energy Costs

The relatively low operational costs of this new harvesting method are an added benefit, as the cost of operation is substantially less than centrifuging and can be run in some cases by solar power or other alternative forms of energy.

One more area of study would be the use of gases developed by the system to power fuel cells attached to the unit.

1 http://en.wikipedia.org/wike/Iron_fertilization

## Conclusion

OriginClear's Electro Water Separation technology has demonstrated unique and highly beneficial advantages for the emerging algae market.

The EWS Algae device separates out algae cells, while keeping algae cell walls intact and killing off competing bacteria in the process, thus greatly improving harvested algae shelf life.

The EWS Algae device separates out algae cells, while keeping algae cell walls intact and killing off competing bacteria in the process, thus greatly improving harvested algae shelf life.

It significantly reduces water usage as the EWS Algae through-flow water can be reused and only a small amount of supplemental water is required.

Its continuous operation and ability to selectively harvest mature biomass brings under control two of the major impediments to exponential algae growth, namely shadowing and bacterial infestation.

It can operate as a stand-alone system for continuous harvesting of viable algae cells using very small amounts of electric power, or it can be easily integrated into existing commercial algae extraction systems, which can significantly improve overall productivity while reducing operating costs.

## CONTACT US

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Los Angeles, CA 90016

Toll Free: +1 877-999-6645, Ext 4
Email: sales@originclear.com

**www.originclear.com**

# Test Data

The following test was conducted to examine the bacterial disinfection of the water after harvesting of biomass and the actual results are attached.

## Material and Methods

- EWS Algae A4 (4lpm) in comparison to a centrifuge
- Raceway grown Nannochloropsis <1g/l
- Photo Bio-Reactor (PBR) grown Nannochloropsis <2g/l

The test compared the use of centrifuge versus OriginOil's EWS Algae A4.

## Analysis and Conclusions

Pacific Coast Analytical Services carried out an independent audit. In the raceway extraction case the test showed:

1. An enormous decrease in overall aerobic plate count (APC).

   Centrifuge: 150,000,000

   EWS Algae: 2,500,000 (a drop of 98%)

2. A similar large decrease occurred in the PBR draw.

   Centrifuge: 140,000,000

   EWS Algae: 1,500,000 (a drop of 99%)

3. Storage Time Increase:

   The extracted product from EWS Algae showed remarkable stability after 14 days open storage at the OriginOil laboratory. This would indicate a partial sterilization without loss of cellular life, as the product can and has been re-incubated and found to resume growth.

The re-injected water in case studies conducted at OriginOil, showing greater growth in all cases.

P C A S

# Pacific Coast Analytical Services

15751 Roxford Street Unit F Sylmar CA 91342 Tel: 818-364-7470 Fax: 818-364-7472
www.pacificcoastanalytical.com DOHS #2667 LACSD#10255 FDA Audited A2LA Member

## Analytical Report

| | | | |
|---|---|---|---|
| **Client:** | RL Food Testing Laboratory<br>3976 Ceanothus Place, Ste. B<br>Calabasas, CA 91302 | **Project #:** | [none] |
| **Attention:** | Roger Legg | **Work Order #:** | 12K0094 |
| **Phone:** | (949) 309-0105 | **Received:** | 11/13/2012 |
| **FAX:** | - | | |
| **Client Project Info:** | CCMP 1776 Nannochloropsis salina | **Reported:** | 11/20/2012 |

Dear Roger :

The results in this report apply to samples analyzed in accordance with the Chain of Custody document. Pacific Coast Analytical Services certifies that the results meet all requirements for laboratory performance unless noted in the case narrative or in the report with data qualifiers.

This analytical report is confidential and it is only intended for use by Pacific Coast Analytical Services and its client. The Chain of Custody form is an integral part of it. The report can only be reproduced in full with all its attachments and the authorization of Pacific Coast Analytical Services.

Thank you for the opportunity to service your analytical needs. Please feel free to call with any questions.

**Reviewed by:** _____

*Claudio Cardelli, Ph.D.* **Lab Director**

/Enclosure: COC

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## Analytical Report

| | | | |
|---|---|---|---|
| **Client:** | RL Food Testing Laboratory | **Project # :** | [none] |
| | 3976 Ceanothus Place, Ste. B | **Work Order #:** | 12K0094 |
| | Calabasas CA, 91302 | **Received:** | 11/13/2012 |
| **Client Project Info:** | CCMP 1776 Nannochloropsis salina | **Reported:** | 11/20/2012 |

**Client Sample ID #: Grown in 600L raceway & harv. using centrifugal** PCAS Sample ID #: 12K0094-01 (Food)

| Analyte | Result | Min. Det. Limit | Reporting Limit | Units | Analysis Completed | Method | Qualifers |
|---|---|---|---|---|---|---|---|
| Aerobic Plate Count, APC | 150000000 | 10 | 10 | CFU/g | 11/15/12 | FDA-BAM,8th ed,Ch 3 | |
| Coliforms | 30 | 10 | 10 | CFU/g | 11/14/12 | AOAC 991.14 | |
| Escherichia coli | ND | 10 | 10 | CFU/g | 11/15/12 | AOAC 991.14 | |
| Staph aureus (coag. pos.) | ND | 10 | 10 | CFU/g | 11/15/12 | FDA-BAM,8th ed, Ch 12 | |
| Yeast | 1400000 | 10 | 10 | CFU/g | 11/18/12 | FDA-BAM,8th ed,Ch18 | |
| Mold | 1000 | 10 | 10 | CFU/g | 11/18/12 | FDA-BAM,8th ed,Ch18 | |

**Client Sample ID #: Grown in 600L raceway & harv. using origin oil** PCAS Sample ID #: 12K0094-02 (Food)

| Analyte | Result | Min. Det. Limit | Reporting Limit | Units | Analysis Completed | Method | Qualifers |
|---|---|---|---|---|---|---|---|
| Aerobic Plate Count, APC | 2500000 | 10 | 10 | CFU/g | 11/15/12 | FDA-BAM,8th ed,Ch 3 | |
| Coliforms | 140 | 10 | 10 | CFU/g | 11/14/12 | AOAC 991.14 | |
| Escherichia coli | ND | 10 | 10 | CFU/g | 11/15/12 | AOAC 991.14 | |
| Staph aureus (coag. pos.) | ND | 10 | 10 | CFU/g | 11/15/12 | FDA-BAM,8th ed, Ch 12 | |
| Yeast | 3000 | 10 | 10 | CFU/g | 11/18/12 | FDA-BAM,8th ed,Ch18 | |
| Mold | 3000 | 10 | 10 | CFU/g | 11/18/12 | FDA-BAM,8th ed,Ch18 | |

**Client Sample ID #:** Grown in PBR & harv. with CentrifugePCAS Sample ID #: 12K0094-03 (Food)

| Analyte | Result | Min. Det. Limit | Reporting Limit | Units | Analysis Completed | Method | Qualifers |
|---|---|---|---|---|---|---|---|
| Aerobic Plate Count, APC | 140000000 | 10 | 10 | CFU/g | 11/15/12 | FDA-BAM,8th ed,Ch 3 | |
| Coliforms | ND | 10 | 10 | CFU/g | 11/14/12 | AOAC 991.14 | |
| Escherichia coli | ND | 10 | 10 | CFU/g | 11/15/12 | AOAC 991.14 | |
| Staph aureus (coag. pos.) | ND | 10 | 10 | CFU/g | 11/15/12 | FDA-BAM,8th ed, Ch 12 | |
| Yeast | 12000 | 10 | 10 | CFU/g | 11/18/12 | FDA-BAM,8th ed,Ch18 | |

# Pacific Coast Analytical Services

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www.pacificcoastanalytical.com DOHS #2667 LACSD#10255 FDA Audited A2LA Member


## Analytical Report

| | | | |
|---|---|---|---|
| **Client:** | RL Food Testing Laboratory | **Project # :** | [none] |
| | 3976 Ceanothus Place, Ste. B | **Work Order #:** | 12K0094 |
| | Calabasas CA, 91302 | **Received:** | 11/13/2012 |
| **Client Project Info:** | CCMP 1776 Nannochloropsis salina | **Reported:** | 11/20/2012 |

**Client Sample ID #:** Grown in PBR & harv. with CentrifugePCAS Sample ID #: 12K0094-03 (Food)

| Analyte | Result | Min. Det. Limit | Reporting Limit | Units | Analysis Completed | Method | Qualifers |
|---|---|---|---|---|---|---|---|
| Mold | 40000 | 10 | 10 | CFU/g | 11/18/12 | FDA-BAM,8th ed,Ch18 | |

**Client Sample ID #:** Grown in PBR & harv. with OriginOil AppliancePCAS Sample ID #: 12K0094-04 (Food)

| Analyte | Result | Min. Det. Limit | Reporting Limit | Units | Analysis Completed | Method | Qualifers |
|---|---|---|---|---|---|---|---|
| Aerobic Plate Count, APC | 1500000 | 10 | 10 | CFU/g | 11/15/12 | FDA-BAM,8th ed,Ch 3 | |
| Coliforms | ND | 10 | 10 | CFU/g | 11/14/12 | AOAC 991.14 | |
| Escherichia coli | ND | 10 | 10 | CFU/g | 11/15/12 | AOAC 991.14 | |
| Staph aureus (coag. pos.) | ND | 10 | 10 | CFU/g | 11/15/12 | FDA-BAM,8th ed, Ch 12 | |
| Yeast | 26000 | 10 | 10 | CFU/g | 11/18/12 | FDA-BAM,8th ed,Ch18 | |
| Mold | 5000 | 10 | 10 | CFU/g | 11/18/12 | FDA-BAM,8th ed,Ch18 | |

NOTE: ND = Non-Detected

## Pacific Coast Analytical Services

15251 Rayford Street Unit F Sylmar CA 91342 Tel 818.364.7470 Fax 818.364.7472

CHAIN OF CUSTODY

Page 1 of 1

| | | | |
|---|---|---|---|
| Company: RL Food Testing Lab | Bill to: | Turn Around Time: ( ) RUSH (call for upcharge & time) (✓) Normal (10-15 working days) | Work Order: 12K0094 |
| Address: 3976 Ceanothus Place, #B Calabasas, CA 91302 | Address: | Method of Transport: ( ) Client ( ) PCAS (✓) Other Fedex | Condition of Sample: (✓) Ambient ( ) Cold _____ °C ( ) Frozen: |
| Phone: 949-309-0105 Fax: | P.O. #: Prepaid ( ): | | Sample Condition (✓) Sealed (✓) Accepted ( ) Chilled ( ) Preserved |
| Contact Name: Roger Legg | Project Name: CCMP 1776 *Nannochloropsis salina* | Special Instructions: | |
| E-mail: roger@rlfoodtestinglaboratory.com | Project #: | *There is a total of 8-50ml. 4 sets with duplicate samples for each set. | |
| Sampled by: Roger Legg | Signature: | | |

| LAB ID | DATE | TIME | MATRIX | SAMPLE DESCRIPTION | CONT. | ANALYSIS REQUESTED | EXPECTED LEVEL/ METHOD |
|---|---|---|---|---|---|---|---|
| 12K0094 -1 | N/A | N/A | Food | Grown in 600L raceway & harvested using centrifuge 11/5/12 | 2* | APC, Yeast& Mold, Total Coliforms, E.coli & Staph Coagulase | |
| -2 | | | | Grown in 600L raceway & harvested using origin oil appliance 11/5/12 | 2* | APC, Yeast& Mold, Total Coliforms, E.coli & Staph Coagulase | |
| -3 | | | | Grown in outdoor photobioreactor & harvested using centrifuge 11/6/12 | 2* | APC, Yeast& Mold, Total Coliforms, E.coli & Staph Coagulase | |
| -4 | | | | Grown in outdoor photobioreactor & harvested using origin oil appliance 11/6/12 | 2* | APC, Yeast& Mold, Total Coliforms, E.coli & Staph Coagulase | |
| | | | | | | | |

| | | | |
|---|---|---|---|
| Relinquished by: Client | Date N/A | Time N/A | Received by: Fedex |
| Relinquished by: Fedex | Date 11/13/12 | Time 15:30 | Received by: |
| Relinquished by: | Date | Time | Received by: |

**Abbreviation:**

**CONT** Container
**DW** Drinking Water
**F** Food