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RESEARCH ARTICLE

Effects of Electromagnetic Hydrolysis on Algal Concentration in Warm, Stagnant Surface Water

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ARTICLE HISTORY

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Abstract: ***Background*:** The study was conducted in-situ at the INCA Pond system in the City of Boynton Beach, Florida which has experienced issues with the formation of harmful algae blooms that create nuisance complaints and unhealthy conditions in the water and surrounding area.

***Objective*:** The EMOH device is designed to supersaturate water as a means to deter harmful algal blooms. This pilot study was conducted to determine if an Electromagnetic Hydrolysis (EMOH) device can improve the health of residential surface water by adding dissolved oxygen to the water to allow the existing bacteria to remove the substrate that provides a food source for blue-green algae outbreaks when combined with naturally occurring aerobic bacteria.

***Methods*:** Combining the EMOH device with naturally occurring aerobic bacteria demonstrated that a pond that normally contained a low DO and copious amounts of algae, would contain fewer algal blooms, that the bacteria would consume the detrital layer on the bottom of the pond that acts as nutrient source for the algae and that DO levels increase with temperature, in contrast to expectations. Four configurations were compared.

***Results*:** The EMOH device successfully reduced the detrital layer on the bottom of the pond and experienced fewer algal blooms. The use of surface aeration permits the oxygen to escape, so having the EMOH discharge below the surface increases efficiency.

***Conclusion*:** The EMOH device successfully accomplished its intended goals.

Keywords: Aeration, algae reduction, detrital matter removal, nutrients, eutrophication, harmful algal blooms.

1. INTRODUCTION

Outbreaks of cyanobacteria (or blue-green algae) are a world-wide phenomenon of toxic aquatic life prone to areas of high nutrient (phosphorus and nitrogen) levels [1]. These outbreaks occur in diverse habitats, including freshwater, brackish, and marine environments as plankton (free floating) mats and periphyton (attached to surfaces) [2]. The first recorded bloom of cyanobacteria was in Australia's Lake Alexandria during 1878, in which livestock and pets died after consuming algae contaminated waters [3]. Later in 1996, water tainted with cyanobacterial toxins led to the death of 55 patients seeking dialysis treatment in Brazil [3]. Beyond the dangers of toxins, dead algae resting on the beds of streams and ponds create anerobic, eutrophic conditions as they decompose, which may cause mass mortalities of fish and other aquatic wildlife [4].

Algal blooms have a normal progression, from single celled organisms to large multi-organism clusters that develop over a period of weeks [2]. Nutrient loading from runoff and warm surface waters induce excessive growth of algae, causing eutrophication [5]. While algae exist in water bod-

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ies without being visible preceding blooms, however, blooms create issues with residents with respect to odors, aesthetics and dead fish. The mats of blue-green filamentous algae create serious issues by reducing oxygen levels in the water [2]. Some species of blue-green algae produce spore-like akinetes that settle into the sediment and can survive for months before being disturbed and redistributed in the water column [3].

Florida is an ideal location to study algal blooms. The state has a warm, humid environment, where warm water and nutrients create the potential for a eutrophic aquatic environment that is highly susceptible to algae blooms during the summer months when ambient temperatures rise, and summer showers increase nutrient loading from surface runoff. Such factors include lake morphology, water circulation patterns, the amount and intensity of sunlight, water temperature, grazing pressure from plant-eating fish, viruses, and microbial mechanisms [6]. Complicating matter is that urban ponds are typically used for stormwater runoff - making them ideal locations for algal blooms.

The City of Boynton Beach, Florida ("City") has a system of interconnected ponds, named the Intracoastal Neighborhood Association (ICNA) pond system, has experienced a number of algae blooms over the past 10 years. The INCA pond system consists of 4 interconnected ponds that discharge through a single slide gate into Florida's Intracoastal Waterway. The tributary area for the ponds includes mangroves just upstream of the ponds that can leach high organic content to the ponds, and single-family residential homes and a few commercial lots which can contribute nutrients to the ponds. The City operates decorative fountains in 3 of the 4 ponds. Those 3 are periodically treated with an EPA registered algaecide application and manual removal of algal mats on the surface. Algaecide application is effective for algae population control, but the dead biomass settles to the bottom of the ponds, providing a reservoir of stored nutrients in the benthic detrital layer for potential re-release later. Skimming of algae is a temporary and labor-intensive solution that is soon followed by rapid regrowth because the nutrient source is not addressed. Meeroff *et al.* [7] noted that appreciable amounts of detrital matter can encourage the growth or regrowth of bacteria during a study of coastal Taylor County, FL before and after septic tanks were replaced by a sewer network. Carsey *et al.* [8] also identified the regrowth issue as a problem within the Lake Worth Lagoon.

Bloetscher *et al.* [9] tested a potentially cost-effective and more sustainable solution - the Electromagnetic hydrolysis (EMOH) device. The EMOH device was previously tested for treating high-strength industrial wastewaters [10-12]. In these experiments, the researchers demonstrated that the EMOH device could reduce TOC by 75% in 24-48 hrs. Lakner [10] also demonstrated that the device entrained high concentrations of oxygen, which created an oxygen supersaturation condition when used in treating high strength industrial wastewater. It was suggested that the EMOH process, would decrease benthic nutrients from prior algaecide treatments, thereby reducing the bioavailable nutrients in the water column and eliminating the need for algaecide application (per email from A. Prymas in 2016).

As a result, the goals of this study were two-fold: since a prior study showed the potential for the EMOH devise to improve water, 1) what was the best configuration for the EMOH effluent and 2) how successful would EMOH be at reducing the detrital mat on the bottom. Success would be achieved if 1) the algal mats did not occur in the INCA pond 3 in the absence of the algaecide, and 2) the detrital mat layer decreased.

2. METHODOLOGY

The INCA pond system is shown in Fig. (**1**). The pilot study was conducted in the INCA pond system, located in the City of Boynton Beach, Florida. For this pilot study, the proprietary EMOH device was provided by AEQUION LLC (refer to Fig. **2**). The EMOH device is a static unit that pulls atmospheric oxygen into the water *via* venturi meter to increase the dissolved oxygen levels to saturation. Untreated influent is fed *via* a pump through a channel of electro-magnets within the unit. The unit was installed at the INCA 3 pond in 2016 and was operated 24 hours per day. Water was drawn into the EMOH device from the center of the pond *via* influent piping, one-inch PVC, and was secured to the pond floor *via* clay brick weights. The device is made of 2-inch diameter PVC and attached to a pump that operates at 80 gpm. Approximately, 10-15% of the flow is

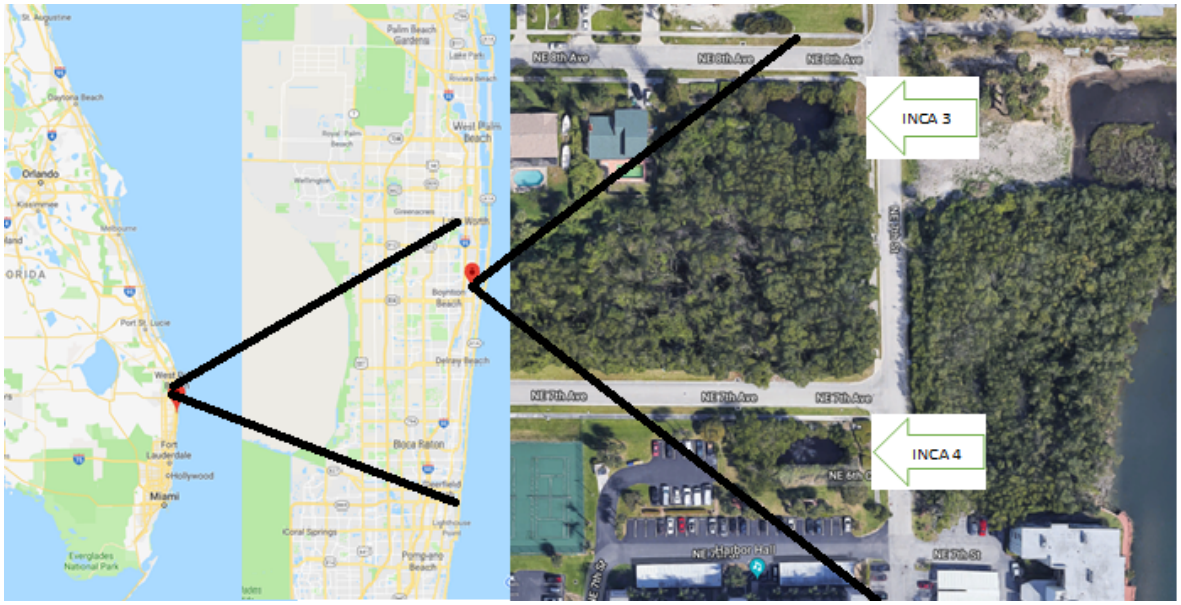

Fig. (1). INCA Pond locations. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

Fig. (2a and b). EMOH device connected to 1 HP pump with PVC piping. Nanobubbles at the surface, rising from near the bottom, shown in 2b. (courtesy Matt Iles and Brian Bailey).(*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

bypassed through the venturi meter. Flow through the EMOH device was generated by a 1.5 horse-power centrifugal pump located on the pond bank. Fig. **3** shows the location of the EMOH device in INCA 3 and to the south, the location of the INCA 4 control. Two points were sampled in INCA 3 (labeled 3A and 3B). One was near the shore and the other farther out in the pond, but both from the north side as shown in Fig. **3**.

To aid the effect of adding oxygen, the venturi meter creates a vacuum to the pipe network up-stream of the electromagnetic chamber. The vacuum is powered by running high velocity water though a tee connection open to the atmosphere. The resulting

Fig. (3). Testing Sites for INCA Pond 3 and 4. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

low pressure draws in ambient air into the pipe, aerating the well-mixed effluent in the pipe due to turbulent conditions. The final discharge was tested using four configurations. The summer 2016 test used a pipe to carry the treated water under the surface [9] (Fig. **4**.) The City requested that the EMOH treated water sprayed into the air like the surface aerators (Fig. **5**). The surface aerator was removed for the fall of 2018, and a turndown pipe added in March 2019 to push the EMOH treated water toward the bottom (Figs. **6** and **7**). The results of these datasets were compared to demonstrate how aeration should be implemented.

Microbial growth media supplements (CBX Optimizer and CBX Sniper) that affect cell wall permeability and cellular metabolism of organic matter for faster rates of bio-oxidation, were added

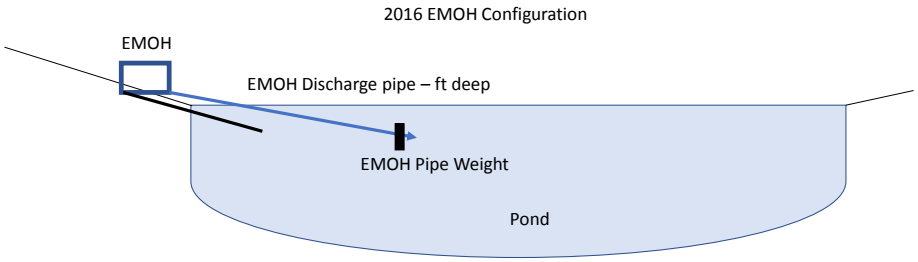

Fig. (4). 2016 configuration. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

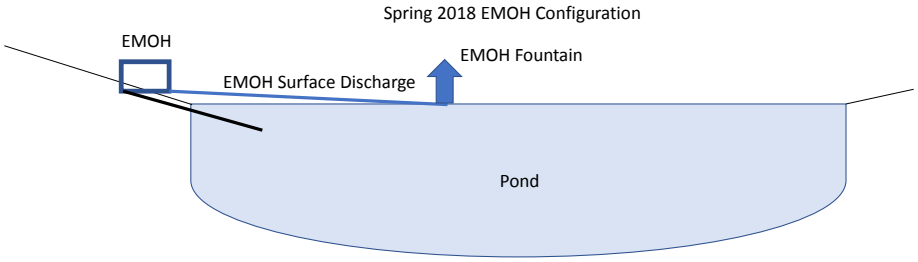

Fig. (5). Spring 2018 configuration. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

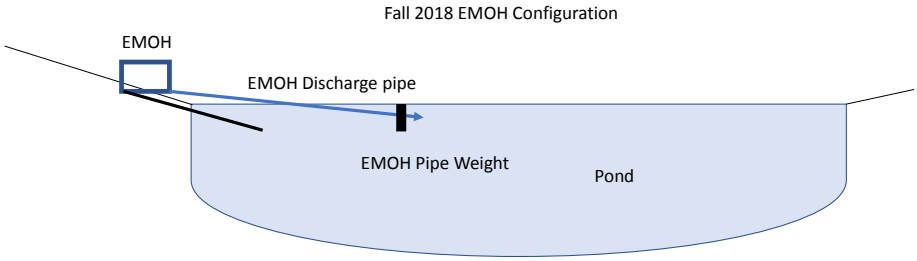

Fig. (6). Fall 2018 configuration. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

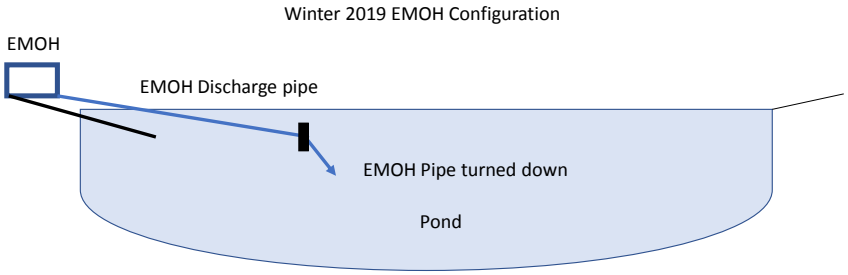

Fig. (7). Winter 2019 configuration. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

Table 1. Samples Collected for INCA 3 Pond.

Parameter	Monitoring Locations (depicted on an Exhibit, Map, Sketch, *etc.*),	Methods of Monitoring for each Parameter (grab Samples, *etc.*),	Reason to Sample
Temperature	From bank each pond	Grab/probe	Baseline changes in water quality
pH	From bank each pond	Grab/probe	Baseline changes in water quality
Conductivity	From bank each pond	Grab/probe	Baseline changes in water quality
TDS	From bank each pond	Grab/probe	Baseline changes in water quality from lagoon transfer
DO	From bank each pond	Grab/probe	Baseline changes in water quality EMOH or fountain
DO saturation	From bank each pond	Grab/probe	Baseline changes in water quality EMOH or fountain
ORP	From bank each pond	Grab/probe	Baseline changes in water quality EMOH or fountain

to the EMOH treated pond. This growth media additive encourages competition between aerobic biological families and the pond algae for nutrients, hypothetically reducing algal populations. INCA Pond 3 was originally treated with CBX Optimizer and CBX Sniper along with EMOH daily treatment. The loading rate of CBX Sniper applied was one gallon per month. The application of CBX Sniper was achieved *via* blower backpack. One-gallon of CBX Sniper was loaded into the hopper of the backpack and sprayed across the surface of INCA Pond 3 from two positions on the bank. The effort was taken to maintain a steady arcing motion with the nozzle during application to apply for uniform coverage.

Data collection at INCA Pond 3 occurred in two stages. Data was collected throughout much of 2016 by hand (*i.e.* a person went to the site to collect data and delivered it to a contract lab). The project was suspended in 2017 before a return in 2018 (client request). New baseline data was collected by hand in February and March, 2019. The next three months of the collection included the activation of the EMOH device and seeding of INCA Pond 3 with a growth media additive. In September 2018, data collection was conducted in a semi-weekly effort, using a digital water quality sensor (AquaTroll 600) to record dissolved oxygen content, water temperature, and barometric pressure so that corrections for dissolved oxygen could be undertaken if needed. Two samples were tested by Florida Spectrum Environmental Services for HPC, COD and BOD were taken in 2018, as was one test for copper in INCA 3 to ensure this pond was not received treatment like the adjoining ponds. The samples were as noted in Table **1**.

A prior effort to study a potential option to address algae in the INCA ponds is discussed in Bloetscher *et al.* [9]. In this study, it was noted that ponds had a thick layer of benthic debris. Samples of this debris layer indicated that it was mainly comprised of organic matter, presumably dead algal biomass resulting from the application of algaecides. In some areas, the detrital layer was 24 inches thick [9]. Monthly samples of the detrital layer depth were collected to track changes in growth in the submerged algae bed. To test the depth of the detrital layer, a custom measuring device (refer to Fig. **8**) was constructed out of clear plastic PVC pipe and fittings. A twelve-foot length of clear 1/2-inch PVC was marked with one-inch graduations. The top of the 12-foot length was capped with a PVC ball valve, when closed will hold pressure in the body of the measuring device. To use the measuring device, the ball valve was moved to the open position, the body of the device was inserted into the pond, through the soil layer, until it met with observable resistance, the ball valve was closed, and the device was removed from the water to record the depth of the detrital layer to the nearest inch. Five samples were collected across the centerline of the pond from east to west (Fig. **9**). Procedures for determining detrital layer depth testing were consistent in all phases.

Fig. (8). Tube used to get data on detrital layer. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

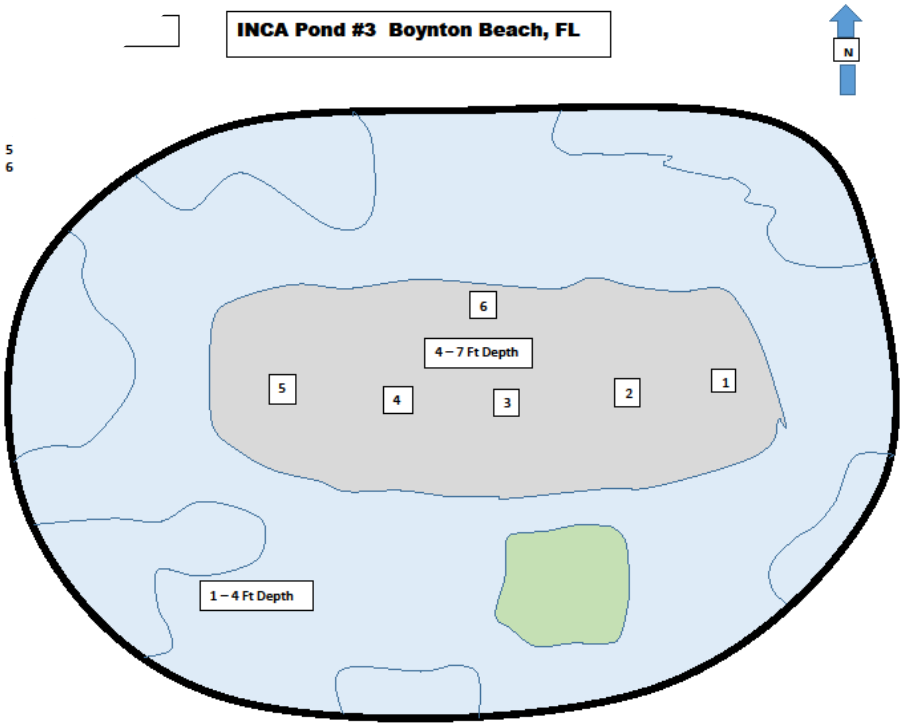

Fig. (9). Detrital layer sampling locations – Similar in both ponds. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

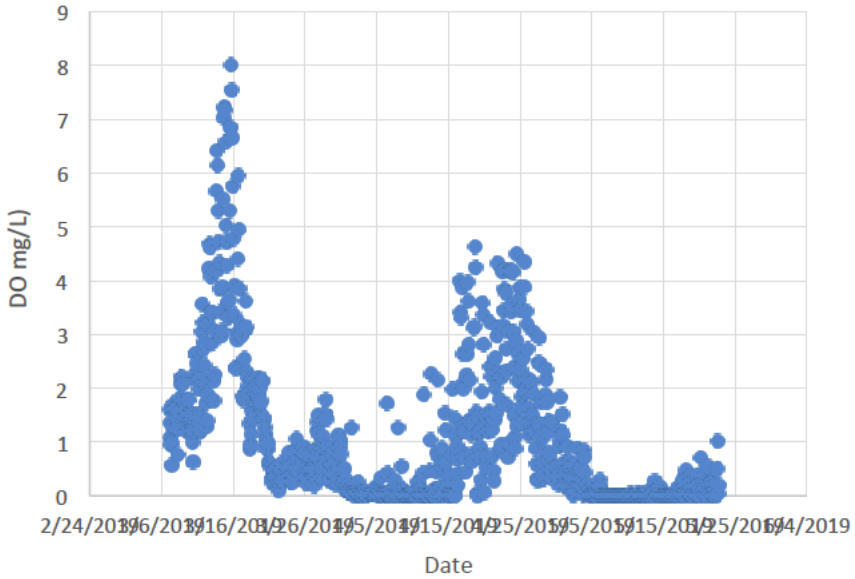

Fig. (10). EMOH device – Spring 2019 – note where the EMOH device failed due to electrical outages, the DO decreased quickly. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

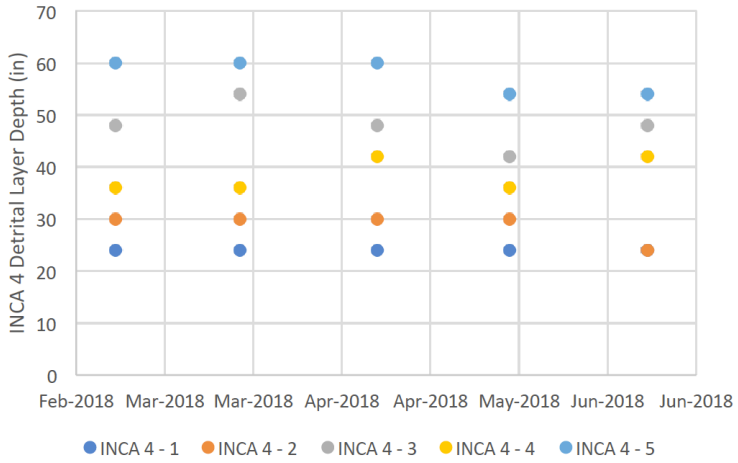

Fig. (**11**). INCA Pond 4 Detrital Layer Depth. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

3. RESULTS

The samples analyzed by Florida Spectrum Environmental Services for HPC, COD and BOD indicated no BOD, too numerous to count for HPC and 52 mg/L in both cases for COD. No copper was detected in INCA 3. These results indicate that the bacteria are active and performing the goal of reducing nutrients in the water.

The data collected in Spring 2018 was compared to Bloetscher *et al.* [9] and subsequent data in Fall 2018 and March 2018 when changes to the aeration system occurred. It was noted that the EMOH device kept having electrical failures during the spring of 2019. When the EMOH device was on, the DO climbed significantly. When the device failed, DO declined (Fig. **10**).

During the spring/summer of 2018, the detrital layer depth increased slightly compared to the results at the start of April 2018. Figs. **11** and **12** showed the variation in depth of organic matter across the beds of INCA Ponds 4 and 3, respectively. Note that the INCA 3 pond had a significant change during the 2016 experiment. The EMOH unit was identified as the causal effect of encouraging the bacteria to consume the detrital layer in 2016. The detrital layer was not rebuilt in the 9 months the EMOH unit was not operating. The INCA 4 pond had no such benefit and started

with a much thicker layer. In both cases, the detrital layer was the layer decreased slightly during the summer but INCA3 remained a magnitude less than INCA 4.

Analysis using PCA methods indicated that there were 355 days of data. Table **2** outlines the basic statistical parameters of all the data. Table **3** is a correlation matrix that demonstrated limited correlation between temperature, dissolved oxygen and conductivity. Fig. **13** is a Scree plot that shows that the majority of variance among datapoints involves 3 factors. Factor 1 is primarily constituted by dissolved oxygen (Tables **4** and **5**). Table **6** shows the days and percentage of time the EMOH device operated under each of the 4 protocols shown in Figs. **4-7**, plus a scenario with no EMOH operating. A discriminant analysis indicated that the centroids of data for each of the scenarios plus the EMOH are not operating. Fig. **14** shows the different centers. However, while Fig. **15** shows that the linear regression solution for the data could be used to predict the operating protocol, the model was poor in predicting protocols 2 and 4 (Table **7**). The latter issue is likely due to unreliability of the power system used to operate the EMOH unit since March 2019 as observed in Fig. **10**. Fig. **16** shows the counterintuitive finding that DO rose with temperature which can only be explained by the EMOH unit.

With respect to algal blooms, the blooms experienced in 2016 and prior did not return in 2018 or 19 (Figs. **18** and **19**). The only change was the addition of the EMOH device.

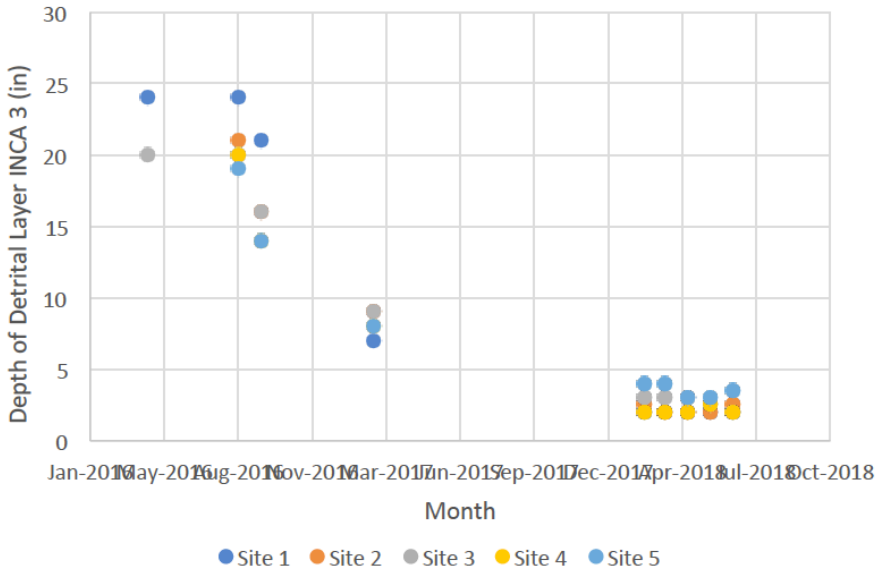

Fig. (12). INCA Pond 3 Detrital Layer Depth which was substantially greater than the decrease in the INCA4 pond. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

Table 3. Summary of variables.

Variable	Observations	Minimum	Maximum	Mean	Std. deviation
Unit Config	355	0.000	4.000	2.392	1.444
DO (mg/L)	355	0.000	12.855	2.250	2.157
% Saturation O2 (% sat)	355	0.000	158.700	28.443	28.426
Specific Conductivity (ÂµS/cm)	355	832.390	3651.000	2018.274	499.594
Temperature (C)	355	19.820	32.800	26.406	3.166

Table 3. Correlation Matrix.

Variables	Unit Config	DO (mg/L)	% Saturation O2 (% sat)	Specific Conductivity (ÂµS/cm)	Temperature (C)
Unit Config	1	0.029	0.003	-0.042	-0.300
DO (mg/L)	0.029	1	0.995	0.317	0.239
% Saturation O2 (% sat)	0.003	0.995	1	0.313	0.300
Specific Conductivity (ÂµS/cm)	-0.042	0.317	0.313	1	-0.290
Temperature (C)	-0.300	0.239	0.300	-0.290	1

Values in bold are different from 0 with a significance level alpha=0.05

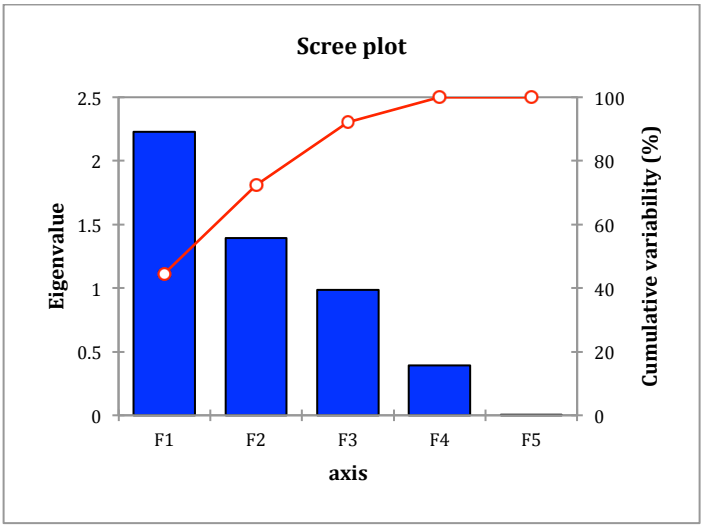

Fig. (13). Scree plot of PCA factors. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

Table 4. Factor Components.

	F1	F2	F3	F4	F5
Unit Config	-0.074	-0.570	0.784	0.235	0.000
DO (mg/L)	0.975	-0.062	0.133	-0.164	-0.034
% Saturation O2 (% sat)	0.985	-0.014	0.123	-0.119	0.035
Specific Conductivity (ÂµS/cm)	0.424	-0.611	-0.565	0.358	-0.001
Temperature (C)	0.349	0.833	0.134	0.409	-0.003

Table 5. Correlations between factors.

-	F1	F2	F3	F4	F5
Unit Config	-0.074	-0.570	0.784	0.235	0.000
DO (mg/L)	0.975	-0.062	0.133	-0.164	-0.034
% Saturation O2 (% sat)	0.985	-0.014	0.123	-0.119	0.035
Specific Conductivity (ÂµS/cm)	0.424	-0.611	-0.565	0.358	-0.001
Temperature (C)	0.349	0.833	0.134	0.409	-0.003

Table 6. Percent of time for each configuration.

Variable	Categories	Frequencies	%
Unit Config	No aeration	74	20.904
	2016 configuration (fig 5)	30	8.475
	Surface aeration	9	2.542
	6 in below surface aeration	167	47.175
	Deep aeration	74	20.904

Table 7. Confusion matrix.

from \ to	0	1	2	3	4	Total	% correct
0	52	2	0	19	1	74	70.27%
1	2	26	0	2	0	30	86.67%
2	2	2	2	3	0	9	22.22%
3	9	2	0	153	3	167	91.62%
4	11	0	4	31	28	74	37.84%
Total	76	32	6	208	32	354	73.73%

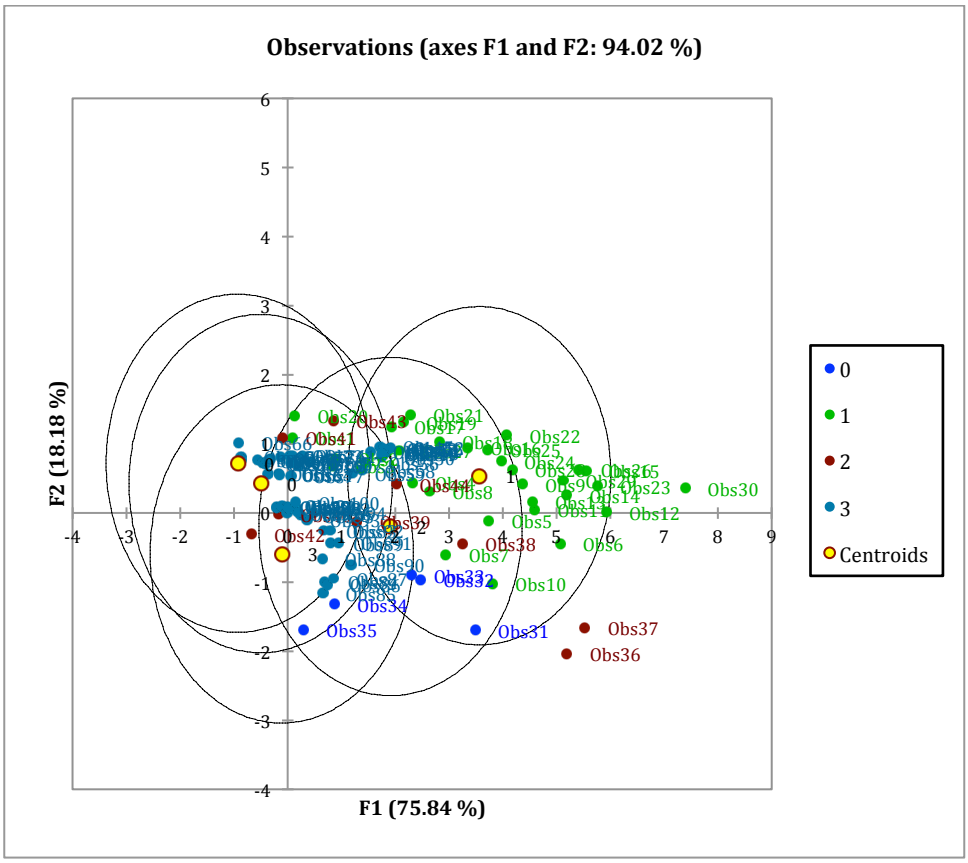

Fig. (14). Centroids of data. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

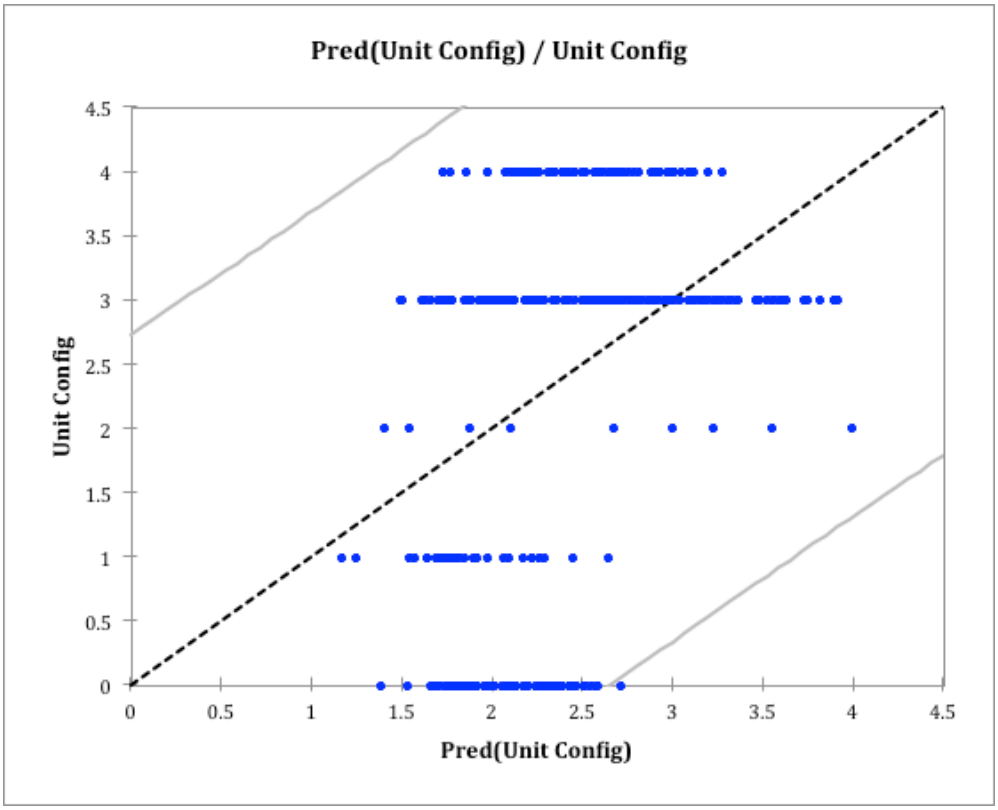

Fig. (15). Predictive Solutions. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

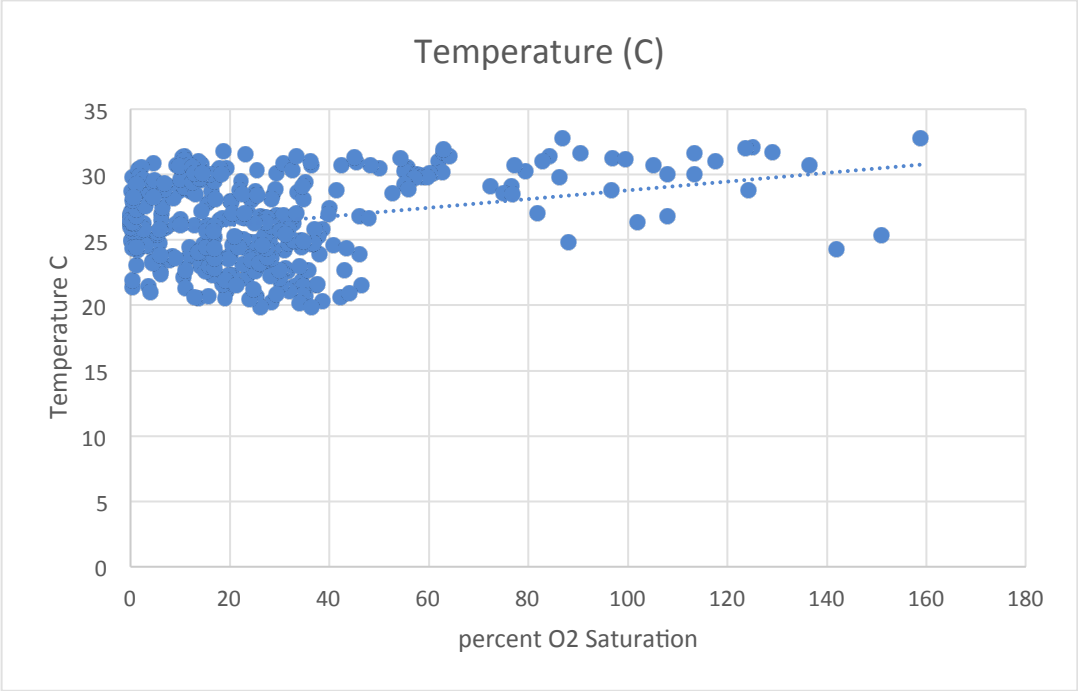

Fig. (17). Oxygen saturation *v* Conductivity. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

Fig. (18). April 2016 INCA3 with algae. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

Fig. (19). May 2019 INCA3 no algae (note bubbles from subsurface EMOH discharge). (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

CONCLUSION

The point of installing the EMOH device was to create supersaturated water to fuel local aerobic microfauna to consume organics in the water, thereby reducing the nutrients available for algal growth. The goals of this study were two-fold: 1) what was the best configuration for the EMOH effluent and 2) how successful would EMOH be at reducing the detrital mat on the bottom. Success would be achieved if 1) the algal mats did not occur in the INCA pond 3 in the absence of an EPA registered algaecide, and 2) the detrital mat layer decreased.

From the perspective of oxygen input, the fountain spray use of the EMOH device must be considered inefficient at higher temperatures compared to the subsurface aeration. This comports with findings from wastewater plants with fine bubble versus surface aeration [13]. In all cases, subsurface flow was more successful at keeping the DO levels up. Conclusion from the testing - EMOH must have a subsurface discharge, which turned 22°-45° toward bottom to prevent the instant exhaust of oxygen to surface. A major benefit is that the EMOH unit may have had a causal effect of encouraging the bacteria to consume the detrital layer as suggested by Bloetscher *et al.* [9] and by Meer off *et al.* [7]. Hence pointing the EMOH effluent, towards the bottom is more appropriate than the surface aeration. The photographic evidence taken each month (or more) indicates that the algal mats were note present after the summer of 2016. The first goal is thus met.

With respect to the detrital layer, the layer remained relatively constant during the summer in INCA 3. The INCA 4 pond had ten times the layer thickness. It too remained constant. However, in 2016, the layer decreased from 24 inches to below 8 inches. Thus, the second goal also appears to have been met.

There are improvements that could be made as the site is not ideal for tracking the EMOH efficiency. First, the EMOH device needs a periodic inspection. In particular, the last 6 months were plagued with power outages that shut the system down. The result is that the DO dropped each time and it takes a few days to increase again. In addition, the INCA 3 pond is tidal and there is some interconnection between INCA3 and INCA4 and the Intracoastal Waterway that complicates the results. As a result, some of the benefits at INCA4 may be due to EMOH, and the oxygen at INCA3 may be impacted by ebbs and flows to the Intracoastal Waterway. The site is not ideal but does show that EMOH will increase DO with temperatures, and that the bacteria will consume the substrate in the detrital layer. A more controlled pond, with a controlled companion, would be of greater benefit.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

All data used in this research was generated by the authors. The data supporting the findings of the article is available *via* dropbox by request to the lead author.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

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