Regulatory Compliance of H Retention Basin Using Rhombo Balls – 16151

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ABSTRACT

Elevated pH conditions in the Savannah River Site 281-8H Retention Basin will have to be resolved prior to the issuance of a new National Pollutant Discharge Elimination System permit. The 281-8H retention basin collects rain water runoff, cooling tower blow downs and steam condensate from H Area Tank Farm operation processes. The basin discharges to a South Carolina Department of Health and Environmental Control National Pollutant Discharge Elimination System permitted outfall, H-12. The permit requires the outfall to meet certain discharge requirements. The National Pollutant Discharge Elimination System permit requires the pH to be within the range 4.8 to 8.5. The 281-8H Retention Basin has a steady history of elevated pH levels, above 8.5, especially during the warmer months of the year, normally March through October. The rise in pH has been attributed to the exponential growth of algae which occurs during the warm months of the year. The increased algae colonies undergo photosynthesis which depletes the CO_2 in the basin water and subsequently raises the pH level. The current permit allows simultaneous discharge of low pH well water, pH between 4.6 and 5.0, and the 281-8H Retention Basin water which provides blending to achieve regulatory compliance. The regulatory agency indicated in 2010 that adding well water to achieve compliance of pH limits will not be allowed when the new permit is issued in the future. Therefore, a solution to the high pH had to be identified and implemented in order to ensure regulatory compliance.

A system engineering evaluation was conducted to determine the best solution to the large algae colonies and high pH levels. The evaluation identified options in four primary categories as well as some combination of those categories to control algae growth and to ultimately increase the amount of CO_2 in the basin. Eleven evaluation criteria were developed for the various options, and a percentage (out of 100%) was assigned to related groups of criteria. Twenty-six options were evaluated during this process. The highest ranking options determined from the evaluation were the 12-sided Rhombo ball floating cover, biological digester and a combination of the digester and the floating cover. Option 3, a combination of the top two choices, was chosen as the best approach. The Rhombo cover along with the initial shock application of a biological digester has worked to eliminate algae growth and lower the pH level. The Rhombos have significantly lowered the basin pH level from greater than 9 to less than 7, which is within the regulatory compliance pH requirements of 4.8 to 8.5.

The system engineering evaluation and subsequent solution chosen are useful in many venues. The application of the 12 sided Rhombo ball's unique ability to nestle together no matter which way they turn is advantageous to applications/problems that need to block 99.99% sunlight from a body of water. The 281-8H Retention

Basin required nine 18 wheeler truckloads with trailers that were 16.2m (53Ft) long and filled with Rhombo balls. The basin required a total of approximately 700,000 Rhombo balls to be fully covered. They are easy to install and handle. The Rhombo balls have wind resistance up to 120 Km/hr (75 MPH) and have a life expectancy of 25 years. This application can be used to control plant and algae growth and is effective in evaporation reduction at 99%.

INTRODUCTION

The 281-8H Retention Basin (HRB) is part of a Savannah River Site (SRS) facility known as the Effluent Treatment Project (ETP). ETP manages the flat-bottomed, sloped-wall, single-lined, impermeable earthen storage basin. The HRB has a maximum holding capacity of approximately 3E7 L (8 million gallons), but is normally maintained below 0.6E7 L (1.5 million gallons). The fenced basin is situated in an open field surrounded by trees and vegetation. It has a surface area of approximately $8450m^2$ ($91,000ft^2$). It was designed to receive potentially contaminated storm water runoff from the H-Area Tank Farms and diverted cooling water as well as cooling tower blow downs, evaporator system steam condensate and tank ventilation steam condensate. If the basin water is determined not to be contaminated and is in compliance, it is discharged to a South Carolina Department of Health and Environmental Control (SCDHEC) National Pollutant Discharge Elimination System (NPDES) permitted outfall, H-12. The NPDES permit requires the outfall to meet certain discharge requirements. One of those SCDHEC permit requirements is pH within the range of 4.8 to 8.5. Finding a solution to maintain the basin to within the permit limits for discharge will be essential for the future NPDES permit requirements.

DESCRIPTION

The HRB has had a steady history of having high pH, typically above 8.5 during the warmer months of the year, normally March through October. Despite the higher pH levels during the warmer months, the H-12 outfall was able to meet the NPDES pH discharge limits. This compliance requirement was accomplished by releasing the basin water simultaneously with a discharge of low pH (4.6 to 5.0) well water. In 2010 SCDHEC informed Savannah River Remediation (SRR) that this practice of blending will no longer be allowed with the impending new NPDES permit. SRR would have to determine the cause of the high pH during the summer months and implement a solution to remedy the problem. Fig. 1 depicts ten years of historical data from 7 May 2003 to 7 May 2013 in which the pH repeatedly is shown to rise above the 8.5 NPDES limit. The algae concentrations, the fluctuation between day and night, as well as the duration and intensity of high temperatures contribute to the variability seen with in the years of graphed pH data. Fig. 2 provides a closer view over a 4 year time span depicting the almost sinusoidal wave of pH readings, that oscillates down during the cooler months, November to February, and up above the 8.5 NPDES limit during the warmer months of the year. During the winter of 2015 the pH remained above 8.5, due to warm weather.

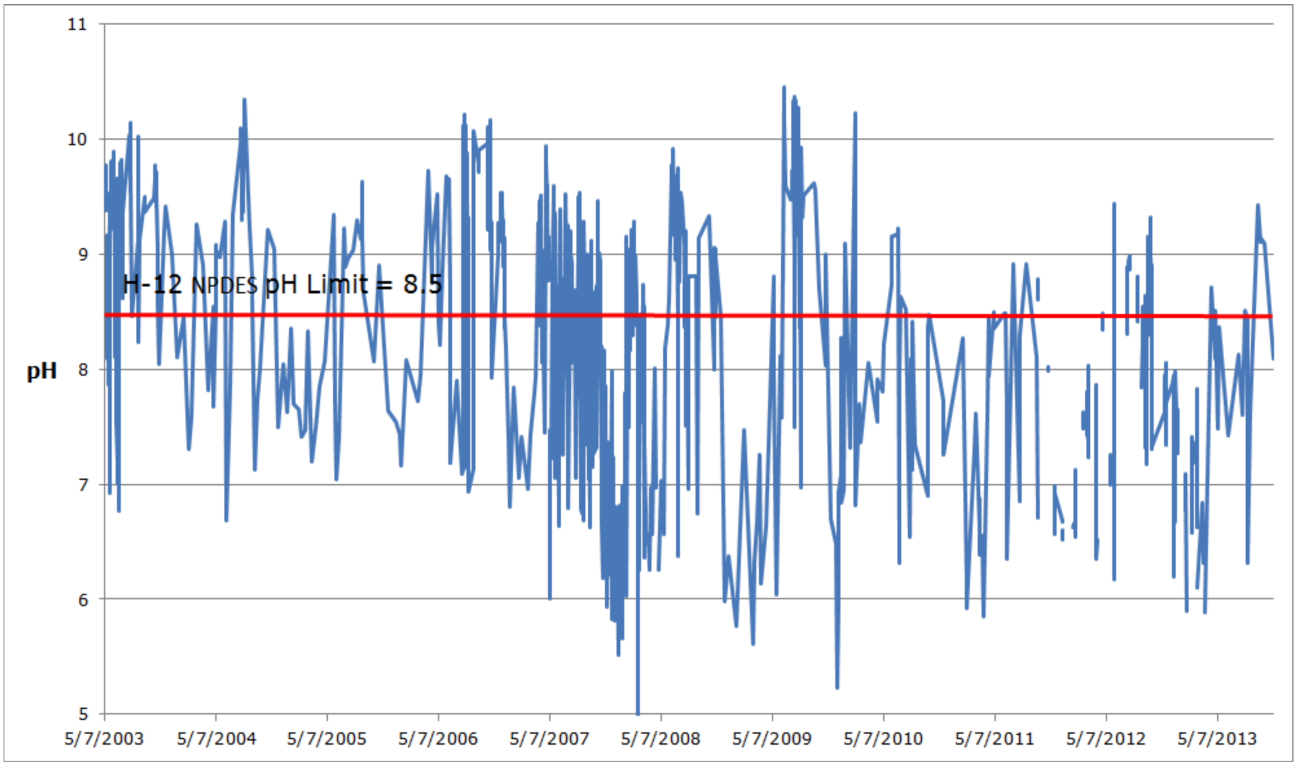

Fig. 1: A Decade of the 281-8H Retention Basin pH data.

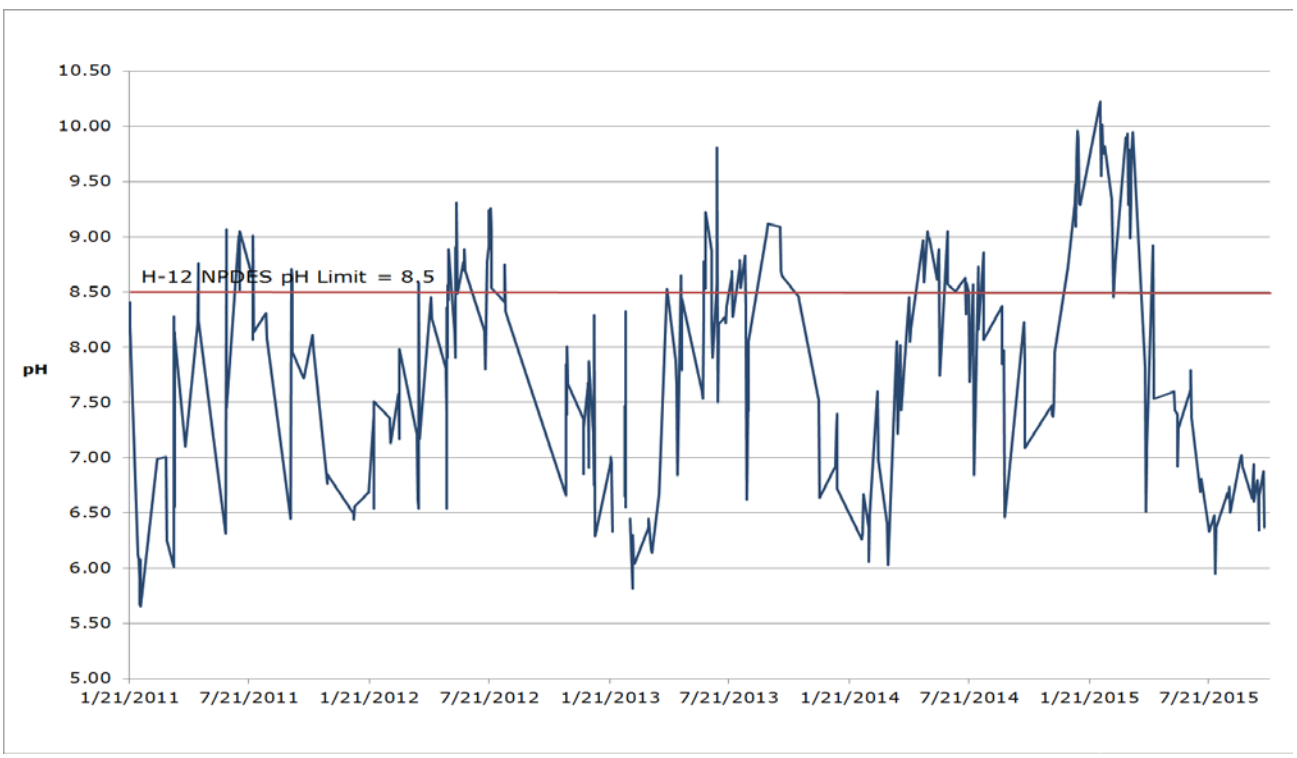

Fig. 2: 281-8H Retention Basin pH data [1]

The HRB has had recorded pH values over 8.5 for many years. The higher pH readings coincided with multiple blooms of algae in the basin. The constant blooming and dying of algae along with the influx of blown leaves and plant debris, various basin animal excrement and sediment from the storm water received from the tank farms had developed 2.5cm to 10 cm (1 to 4 in.) of organic sediment along the basin floor. The decaying organic matter was providing a substantial food source for the ever growing algae blooms. See Fig. 3.

Fig. 3: Algae Laden 281-8H Retention Basin 7/29/2013

The storm water runoff from the tank farms has an average pH of about 6.5 to 7. This pH was much lower than the basin water during warm months of the year. The lower pH occurs because carbon dioxide hydrates in rain water when exposed to air and forms carbonic acid which dissociates to form a hydrogen cation and bicarbonate anion. [2] The same thing will happen when carbon dioxide in air is added to the basin water, the pH will decrease. If you remove carbon dioxide from the basin water, the pH will increase.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \quad \text{(Eq.1)}$$

This process is exactly what the algae are doing during the daylight hours, removing carbon dioxide by the process of photosynthesis. The rate of photosynthesis in the basin is determined by the amount of available sunlight, carbon dioxide and the water temperature. All living organisms continuously undergo respiration and produce carbon dioxide. Respiration rates are affected by the amount of plants and animals in the basin (including microorganisms), water temperature, and bottom sediment. Ultimately, the relative rates of respiration and photosynthesis within the basin determine whether there is a net gain or loss of carbon dioxide. The illustration in Fig. 4 [2] depicts these fluctuations in a high pH pond.

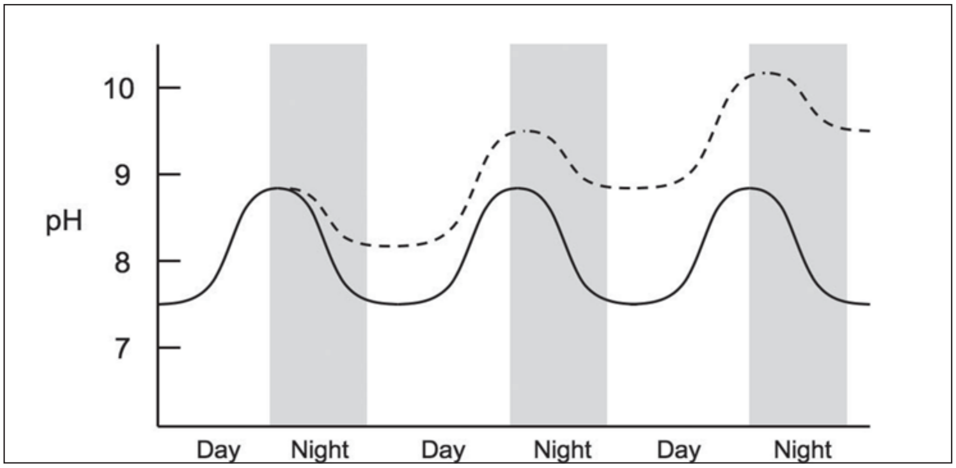

Fig. 4: Typical pH Fluctuations in Ponds

Fig. 4 is an idealized depiction of pH cycling during a 3-day period in two ponds. In both ponds, pH rises during the day as carbon dioxide is removed through photosynthesis and falls at night (shaded vertical bars) as carbon dioxide is added to the water through respiration. The solid line represents pH changes in a pond where carbon dioxide taken up in photosynthesis is offset by carbon dioxide respired at night. The dashed lines represent pH changes in a pond where more carbon dioxide is fixed in photosynthesis than is produced at night, and pH values increase from day to day. [2]

It was determined that reducing the amount of carbon dioxide, eliminating the organic material in the sediment, and blocking the sunlight would effectively reduce or eliminate the algae growth. By eliminating the algae, the basin would be in regulatory compliance. The next step was determining the best way to eliminate or control the algae growth.

METHODOLOGY

An alternative study per Systems Engineering Methodology Guidance Manual was performed to determine the best method to control the algae. [3] The first step was to organize a team of facility experts. The team consisted of a team lead and NPDES compliance and environmental subject matter expert (SME), a project engineer, tank farm/ basin engineer, environmental manager, environmental compliance authority for the ETP facility, ETP operation’s representative, operations facility support SME, ETP radiological control deputy manager and supervisor and the ETP operations lead. The team was educated on the problem with algae growth in the basin and its relationship to regulatory compliance for pH at the H-12 outfall. The team was tasked with determining the best solutions.

Four categories for algae control were chosen and a fifth category was a combination of the existing categories. Each category was chosen based on one of the following factors for algae control; limit requirements for photosynthesis, adjust the pH or destroy the algae. The first category was sun-blocking. It was chosen because algae require sunlight for photosynthesis. The Mechanical treatment category contained options that either killed the algae or eliminated the food source. The chemical/biological option killed the algae, neutralized the pH, removed the food source, or increased the carbon dioxide and decreased the pH. The operational change category neutralizes pH by aeration or treatment. The last category was a combination of a floating cover and another previously discussed option. The table below identifies the algae control categories and lists the corresponding options below.

TABLE I. Algae Control Categories and Options

Algae Control Categories				
Sun-blocking	**Chemical/Biological**	**Mechanical**	**Operational Change**	**Rhombo balls plus**
Category Options				
Floating cover Balls	Acid addition	Ultrasonic device	pH adjustment by aeration in second basin	Recirculation
Floating cover Rhombo balls	Ultraviolet exposure	Aeration – recirculate basin	Treatment at ETP facility	Biological digester
Solid Floating cover	Biological digester	Aeration – recirculate pump		Algaecide
Dye addition	Algaecide	Aeration – recirculate floating pump		Biological digester, recirculate/pump
Fixed exterior cover	CO2 addition – natural matter	Aeration – air injection		Bio. digester floating pump
	CO2 addition – gas injection	Aeration – sprinklers		
		Clean out basin		

Determining the best option would be based on selecting the evaluation criteria, grouping the criteria and assigning a weighted percentage out of 100% to each criterion's importance.

TABLE II. Algae Control Evaluation Criteria

Criteria Grouping	**Percentage of Importance**
Installed cost, Operation cost	30%
Radiological issues, Industrial Hygiene / safety, Auditable Safety Analysis related impacts.	20%
Operating limitations, Maintenance, Operational history in industry	25%
Risk, Permit needs, implementation time	25%

At this point the team was ready to assign a numerical value from 1-10 to each criteria for each option. A score was assigned to each option based on the value to each criterion with in the assigned percentage group. See Fig. 5 for an example of a portion of the Matrix used to analyze the options. [1]

281-8H Basin Algae Abatement/Prevention Options

		Option	Sun-Blocking Options							
			Floating Covers							
			Balls		Rhomb/Hex¹		Solid Cover		Dye Addition	
		Description	Balls floating on surface		Rhomb/hex floating		Solid fabricated cover		Add dye to basin to block sun	
		Mechanism	blocks sun to inhibit algae growth							
Evaluation Criteria	30%	Install Cost	Materials $200K; install minor	8	Materials $200K; install minor	8	Material & installation > $500K	5	Material cost < $2K per application	9
		Operational Cost	Low	9	None	10	Cover dewatering/solids removal	4	Low	9
	20%	Rad Issues	balls could blow out of basin; could install	7	None expected	8	personnel must enter basin to install, move	3	None	10
		IH, Safety Issues	retrieving balls that blow out	8	None expected	10	Issues during install & mod	3	None	10
		ASA-Related Impacts	Slight - sediment sampling cannot readily be performed using current technique	8	Slight - sediment sampling cannot readily be performed using current	8	Slight - sediment sampling cannot readily be performed using current technique	8	None	10
	25%	Operating Limitations	Slight - sediment sampling cannot readily be performed using current technique	8	Slight - sediment sampling cannot readily be performed using current technique	8	Slight - sediment sampling cannot readily be performed using current technique	8	Minimal - addition on continual basis	10
		Maint Requirements	Minimal	9	Minimal	10	Minimal	10	None	10
		Operational History in Industry	Good, but some materials (balls) may blow out of basin; may require install of	7	Works well	10	Some users have had probs with water accumulating on cover	3	Works well, but is intended for ponds that do not turn over	6
		Risk	Potential contamination of balls get outside of CA. Sediment sampling cannot readily be performed using current technique	5	Slight - sediment sampling cannot readily be performed using current technique	8	Issues with cover: water, solids removal; wildlife on cover, sediment sampling cannot readily be performed using current technique	2	Subject to SCDHEC approval; R.61-68 prohibits discoloration of waters of state; 7Q10 flow provides little dilution	2
									Not req'd	

Fig. 5: Options Ranking Matrix

METHODOLOGY RESULTS

The three highest scoring options out of a possible score of 10 included the following:

1. (8.95)Sunlight –blocking: Floating cover (Hexa Armor/ Rhombo cover manufactured by AWTT, Inc.)[4]
2. (8.72)Chemical/biological: Treatment with a biological digester (NT-Max manufacturer New Tech Bio.[5]
3. (8.37)Combination: Biological digester and Rhombo floating cover.

Results for grading all 22 options range from a score of 3.47 to 8.95 in Table III. Four options were excluded from tabulation due to radiological and industrial hygiene issues as well as being impractical.

TABLE III. Graded Option Results

Score	**Option**
8.95	Floating cover, Rhombo/Hex balls
8.72	Biological digester
8.37	Cover and biological digester
8.28	pH adjustment in H cooling water basin
8.18	CO_2 addition with barley straw
8.02	Floating cover, balls
7.78	Dye
7.75	Algaecide
7.63	Clean sludge out of basin
7.63	Recirculate mobile pumps
7.62	Recirculate existing pumps, current piping
7.47	Cover plus recirculate (floating pumps)
7.43	Fixed exterior cover
7.35	Cover plus digester plus recirculate (floating pumps)
7.30	Recirculate existing pumps, modify configuration
7.08	Cover plus algaecide plus digester
6.75	Cover plus recirculate (existing pumps reconfigured)
6.70	Treatment at ETP facility
6.57	Cover plus digester plus recirculate (existing pump)
6.18	Ultrasonic unit
5.03	Solid cover
3.47	Acid addition

The first choice is the Rhombo 114mm size (4.5 in) floating ball cover. [2] The cover is composed of 12 sided shaped Rhombo balls that no matter which way they turn they will nest beside other Rhombo balls giving the appearance of an interlocking floating cover. The Rhombo is not really like a ball it is more like a block. The block-like shape is due mainly because Rhombo balls are not round and do not roll. The floating cover has 99.99% coverage and 120km/hr (75 mph) wind resistance. [4] The high wind resistance is important because the basin is posted as a radiologically contaminated basin. It would not be advantageous to have windblown Rhombo balls outside of the basin and radiological postings. Some other factors that influenced the score were the 25 plus year expected life expectancy and the melting point of 129^0C (264 ^{0}F). [4]

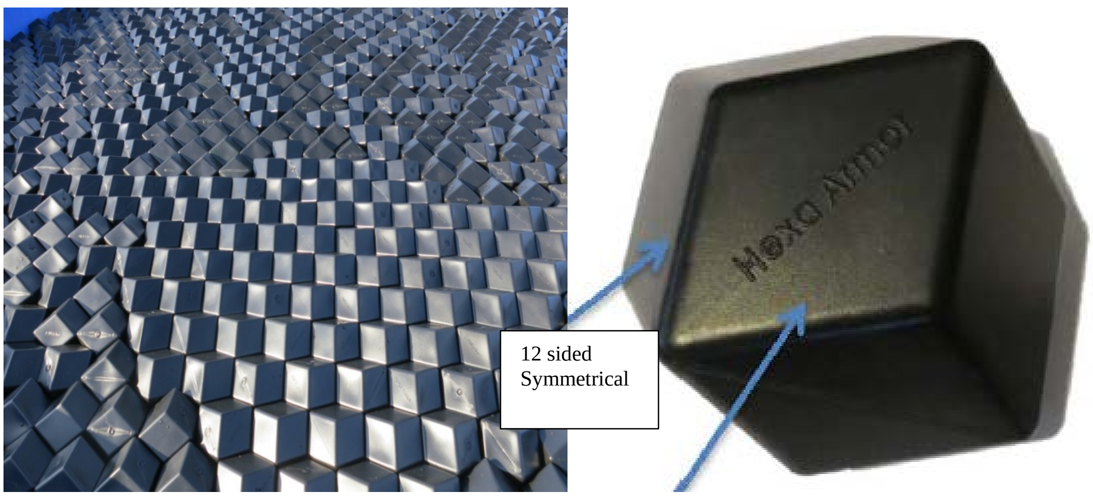

Fig. 6: [a] The Rhombo Floating Cover and Rhombo Ball

Option 3, the Rhombo floating cover and the biological digester, was selected as the team's final solution to the HRB's high pH issue. The cover was chosen to block the sunlight and prevent photosynthesis Fig. 7 is a picture of the 241-8H retention basin filled with the Rhombo cover.

Fig. 7: Rhombo covered 241-8H Retention Basin

[a] Hexa Armor/Rhombo ball , Advanced Water Treatment Technologies copyright Inc. 2007-2013

The biological digester was chosen because it will be a non-invasive way to remove the organic material from the bottom of the basin. The digester accomplishes the breakdown of organic material by the use of the non-pathogenic naturally occurring, non-engineered aerobic and facultative anaerobic bacteria that are contained in an inert carrier medium. The digester breaks down the decomposing organic material, the food supply for the algae. [5] The biological digester was also very affordable, adding up to a couple thousand dollars.

EXPERIMENT

The procurement of the Rhombo shaped balls and the biological digester, was prefaced with a letter to SCDHEC on November of 2014, describing the plans to perform maintenance on the HRB. Once SCDHEC concurred during November 2014, approximately 700,000 Rhombo shapes were procured. It took nine 18 wheeler truck loads; with trailers that were 16.2m (53Ft) long filled with Rhombo balls to fill the HRB. The first truck was received on February 2, 2015 and the last truck load was completed on June 18, 2015. The biological digester, NT-MAX, was procured in January. The manufacture's product information sheet describes the best temperature for application is above 6^0C (47^0F). Subsequently, the biological digester began the recommended dose additions the first week in March 2015. The recommended 7 weekly additions of the NT-MAX were based on a starting amount of 3.17 Kg/ hectare (7 lbs/ acre) and then reduced by 0.45Kg (1 pound) each week ending with .91Kg/ hectare (2 lbs/ acre) on weeks 6 and 7. The HRB basin is 0.85 hectares (2.09 acres). So, all of the digester additions were based on 2 acres. The addition of NT-MAX was completed by the second week in April, 2015. Two maintenance application of 1.81Kg (4 lbs) of NT-MAX were performed monthly for the next two months.

RESULTS

The addition of the free floating Rhombo balls took four and a half months to complete, from February 2015 to mid-June 2015. Once the basin reached approximately 44% coverage, the first significant drop in pH below the required NPDES limit of 8.5 was observed at a pH of 7.8 and then to a low of 6.5. After the initial drop below 8.5, there was a spike above this level at a pH of 9.35. It is believed that this high pH was due to a sample being captured before the basin water was adequately recirculated. The pH level since the April spike has remained consistently within the 4.8 to 8.5 NPDES limit requirement. The basin pH levels have gone from a historically high level, 10.37 during the months of March through October to a low pH recording of 5.95 in July of 2015. The average pH has been around 7. The Rhombo balls distribute themselves in response to wind and water movement in the basin. The Rhombo balls are designed to nestle together, constantly keeping their cover formation. The animal life, mainly turtles, which had been observed in the HRB prior to the addition of the Rhombo balls have vacated the covered basin. The disappearance of the turtles is a plus because it eliminates a source for continued buildup of organic matter. The biological digester was the other essential part of combating the high pH issues. It was added to the HRB once the outside temperature reached above the minimum manufacturer's recommended temperature of 6^0C. The 0.45 Kg (1 pound) water soluble packets when added to the basin water disintegrated as anticipated. The basin was observably clearer by April of 2015. The basin water when seen amongst the Rhombo cover in August of 2015 remained clear. The only issue that has been noticed since the installation of the Rhombo balls, which are really block-like, is that because they do not roll, groups of the Rhombo balls tend to get hung up on the rippled sides of the basin wall liner. The loss of the few Rhombo balls that are now out of the water during low basin levels has not affected the pH levels or allowed for algae growth in the basin. Fig. 8 depicts the results of the biological digester and Rhombo ball cover installation in reducing pH in the 281-8H Retention Basin to levels to below what is required for regulatory compliance.

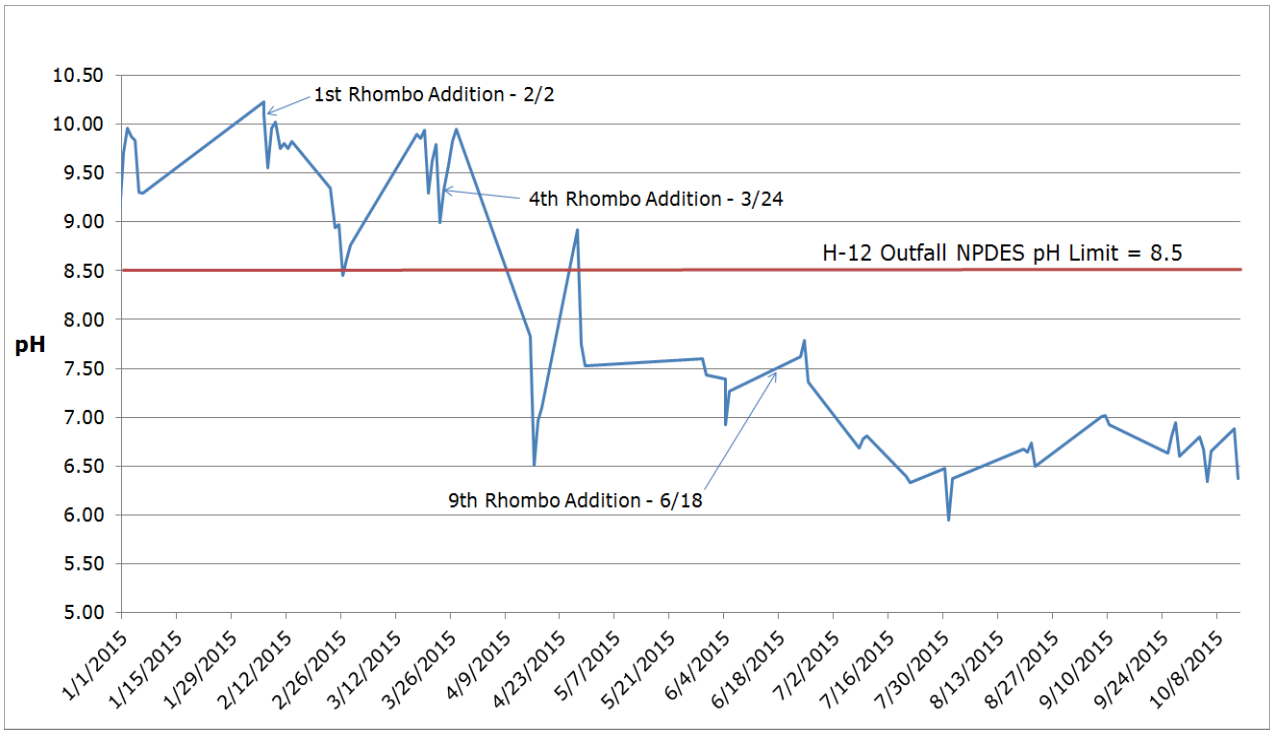

Fig. 8: HRB pH Results with the Rhombo Cover and Digester Addition

CONCLUSION

The introduction of the Rhombo balls and the biological digester from 2/2/2015 to 6/18/2015 yielded significant reduction in basin pH levels. Subsequent to the initial drop of pH levels below the regulatory limit only one pH sample taken exceeded the 8.5 NPDES regulatory limit. This one exceedance was believed to be the result of a lack of recirculation of basin water prior to sampling. The pH results of continued sampling events have remained below regulatory compliance limits throughout the warmer months of 2015 as depicted in Fig.8. The ongoing data collection will support verification of regulatory compliance. It is expected that the 281-8H Retention Basin will continue to meet the SCDHEC NPDES pH requirements when the new NPDES permit is issued.

REFERENCES

1. Jana Ackerman, Q-ERS-H-00013, Rev. 0, Control of 281-8H Basin pH: Options Development and Analysis, October 2014.

2. C. S. Tucker and L. R. D'Abramo, Southern Regional Aquaculture Center, Publication No. 4604, Managing High pH in Freshwater Ponds, July 2008.

3. Systems Engineering Methodology Guidance Manual, WSRC-IM-98-000033, Rev. 2, Appendix A, Alternative studies.

4. Advanced Water Treatment Technologies, Hexa Armor / Rhombo cover specification sheet, copyright AWTT Inc. 2007-2013

5. New TechBio, NT-MAX Pond Treatment Product Information Sheet, copyright 2007 NewTechBio NT-MAX Biological Digester Treatment and care product.