REPORT TO

CDG ENVIRONMENTAL, LLC.
205 WEBSTER STREET
BETHLEHEM, PA 18015

Volume 1 of 1

SUBJECT: EFFICACY OF A 0.3% CHLORINE DIOXIDE SOLUTION (PRODUCT KNOWN AS CDG SOLUTION 3000) FOR ALGAE CONTROL IN AN OPERATING COOLING TOWER WATER SYSTEM

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EXECUTIVE SUMMARY

The product CDG Solution 3000, a 0.3% aqueous solution of chlorine dioxide, was evaluated for efficacy in the killing and controlling of algae deposits in one operating cooling tower located in Denver, Colorado. This project was conducted during an exceptionally warm and sunny period from August 9, 2010 to September 7, 2010, in a cooling tower that historically has had a serious algae problem.

The results of this evaluation clearly illustrated that CDG Solution 3000 is an effective algaecide for use in cooling tower water systems. Immediate and complete kill of algae occurred after the initial product application, which was illustrated by the green algae turning brown (Photos 5 – 6). Following the initial application, no significant algal re-growth was observed for the duration of the 30-day trial. After discontinuation of the CDG 3000, significant algae re-growth occurred within 7 days.

INTRODUCTION

Puckorius & Associates, Inc., an independent water consulting firm specializing in cooling water systems and water treatment technology, was contracted by CDG Environmental, LLC. to demonstrate the performance of their product, designated CDG Solution 3000, for algae control in cooling tower water systems.
This efficacy project is to supply performance data for California DPR registration as an algaecide for use in cooling tower water systems.

Puckorius & Associates, Inc. does not sell chemicals or equipment and has evaluated biocides, corrosion inhibitors, and deposit control chemicals in both its laboratory as well as in operating cooling tower water systems for various clients over the past 10 years.The product, CDG Solution 3000, is an EPA registered proprietary 0.3% aqueous solution of chlorine dioxide. The Material Safety Data Sheet and a copy of the label are included in the appendix. The EPA registration number is 75757-2.
The operating cooling tower with existing algal deposits was selected for this demonstration.

The cooling tower water system is located in downtown Denver, Colorado and primarily used for HVAC and computer cooling service. It cannot be shut

down due to the computer cooling demand. The owner of the cooling tower water system has allowed Puckorius & Associates, Inc. to treat these towers with new products, using extensive monitoring to be sure no adverse action occurred. Detailed information on Puckorius & Associates, Inc. capabilities and experience can be found on their web sites Puckorius.com and watertrainingservices. com.

Water analyses, photos, and physical inspections were used to show the effectiveness and impact of the CDG Solution 3000 for algae elimination and control.

MATERIALS AND METHODS

Solution 3000 Application and Monitoring

This demonstration was conducted for 30 days, from August 9, 2010 - September 7, 2010. The cooling tower did not receive any biocides or algaecides for 6 days prior to the start. This allowed the algae to grow and accumulate significantly in the tower basin (Photo 4). The only algaecide or biocide used during this demonstration was the CDG Solution 3000 (regular scale and corrosion inhibitors, which do not impact algae growth, were present).

The overall experimental plan was to follow the use directions on the product label, which specifies an initial slug dose of 50 mg/L (60:1 dilution) followed by continuous dosing at 5 mg/L. The slug dose was applied by manually emptying five 5-g containers of Solution 3000 into the basin. However, after the initial 50 mg/L slug dose was applied it soon became clear that a dose of 5 mg/L for 24 h/d was excessive. Therefore, in order to minimize the amount of chemical added to the system while still maintaining effective algae control, the follow-up continuous dose was reduced to a level which resulted in a stable chlorine dioxide residual of approximately 0.2 mg/L. For the continuous dosing, the Solution 3000 was fed from 30-g containers, using a standard metering pump (Figure 1). This residual was measured (Hach DPD-glycine method) in samples taken downstream of the cooling tower, where chlorine dioxide losses due to volatilization and destruction by UV radiation appeared to be significant. This dose was applied for 8 – 9 h/d starting on the 3rd day of the trial. The Solution feed rate required to attain these conditions was approximately 1.1 gph. This dosing regimen was found to be more than adequate to prevent re-growth of algae.

The demand on the system did not allow the cooling tower to be shut down and drained, as suggested in the product label. This is typical of cooling tower systems providing cooling for critical equipment. However, as part of its regularly

Figure 1. CDG Solution 3000 being fed from 30-g container during the trial.

scheduled maintenance, the cooling tower basin was vacuumed and cleaned of dead algae on Day 15 of this project. This cleaning provided the opportunity to further illustrate the effectiveness of the CDG Solution 3000 by showing that it prevented algal re-growth for the remainder of the evaluation.

Selection of Monitoring Sites

Photos were taken to illustrate and record the presence of algae in the cooling tower basin and tower fill immediately prior to the application of the Solution 3000. Photos were taken after the initial application and again at frequent intervals (almost daily) during the 30 days to illustrate the efficacy of the product. Although there is an exposed basin on two sides of the tower, the west side basin contained significantly greater algae growth and coating. Because the west side basin represented the "worst-case" conditions in terms of algae (Photos 5 and 14), it became the focus of the project. Photos from two sites on the west side basin (Sites D and E) are provided. Aside from multiple photos taken on the first day of the project, the photos are generally provided in 4-5 day intervals.

Cooling Tower Characteristics

The cooling tower water system utilized in this evaluation is located in downtown Denver, Colorado (Photos 1-3). It is considered a medium-sized system that primarily serves a chiller for air conditioning. This cooling tower sends cool water to the chiller and computers to pick up heat from that equipment and returns warm water to the tower to repeat the cycle. It thus cannot be shut down and drained, which is a deviation from the label instructions.

The cooling tower is constructed of galvanized steel and manufactured by Marley Cooling Tower Company. It is a cross-flow tower with PVC fill and PVC mist eliminators and rated at 500 tons. It supplies cool water at 70-75˚F and receives warm water at 80-85˚F depending upon the outside temperature and humidity. The circulation rate of this semi-closed loop system (make-up water is introduced regularly) is approximately 800 gallons per minute with reduced flow during the weekends. It operates 24/7 and has a total system volume of approximate 1500 gallons. It is connected with mild steel piping to a chiller with copper tubes.

The tower is typical in that it will accumulate and grow algae in the tower basin and the tower fill exposed to sunlight. The algae growth can be a thin coating or a heavy thick growth if not properly and effectively controlled. Live or viable algae are often of a bright green and/or blue-green color and easily identified visually.

Historically, this cooling tower has experienced serious algae problems and obtained mediocre results using other algaecides. The previous algaecide was discontinued for 6 days for this demonstration, which allowed significant re-growth to occur.

The cooling tower basin is open on both sides of the tower. The side that receives the most sunlight, i.e. the "worst-case condition", was the focus of this study. Almost daily cooling tower visits were made between the initial and final CDG 3000 application. A large number of photos were taken to illustrate the effectiveness of the CDG Solution 3000. Only enough are included in this report to illustrate the results.

In addition to regular ORP (oxidation reduction potential) measurements, chlorine dioxide levels and the Solution 3000 feed rate were recorded.

Cooling Water Quality

The water quality in this cooling tower water system was tested several times during the CDG 3000 application and was maintained at essentially these same levels during the entire testing period. Both the average makeup and concentrated cooling tower water analysis is shown in Table 1.

Table 1 Cooling tower water quality (average values).

Constituent	Makeup Water	Tower
Conductivity (microsiemens)	281	1350
Hardness	82	310
Total alkalinity (mg/L as CaCO3)	63	260
pH	7.2	8.4
Chlorides (mg/L as NaCl)	22	105

RESULTS AND DISCUSSION

Chlorine Dioxide and ORP Levels

The chlorine dioxide and ORP levels, for the initial dosing as well as for typical operation during the trial, are given in Table 2. An initial consumption of the chlorine dioxide occurred, as expected, due to reaction with the algae and other organic material in the tower water. A maximum chlorine dioxide residual of 1.35 mg/L was recorded approximately 15 minutes following the initial slug dose. As discussed in Materials and Methods, the average chlorine dioxide residual during the trial was approximately 0.2 mg/L.

The ORP level ranged from 266 (prior to Solution 3000 application) to 600 – 700 microsiemens for a majority of the trial. ORP levels in 600 – 700 microsiemens range are considered very effective conditions for algae destruction.

Table 2 Initial and typical operating conditions during cooling tower trial.

Day	Time	ORP (microsiemens)	ClO2 Residual (mg/L)	Solution 3000 Dosing Status
1	9:00 am	266	0.0	prior to ClO2 addition
1	10:30 am	776	1.35	20 min. after initial slug
1	1:45 pm	440	0.15	start of continuous feed
2	10:00 am	410	0.19	continuous 5 mg/L feed
3	3:00 pm	500	0.19	target residual = 0.2 mg/L
4	10:00 am	535	0.13	target residual = 0.2 mg/L
7	10:00 am	646	0.24	feed at 2.5 mg/L for 8 h/d
15	10:00 am	613	0.17	Basin vacuumed on this day
22	10:00 am	678	0.22	feed at 2.5 mg/L for 8 h/d
30	3:00 pm	313	0.0	after Solution feed discontinued

Algae Destruction and Control

Photos 4 – 14 and 15 – 23 document the initial algae destruction and subsequent control over the duration of the 30-trial for Sites D and E, respectively. The initial conditions are shown in Photos 4, 5, and 14. Overall, after the initial application of Solution 3000, no significant algae re-growth was observed in the basin for the duration of the 30-d trial. The initial slug dose of 50 mg/L dramatically impacted the algal biofilm, as shown in Photos 6 and 15. It should be noted that, as is typical for all cooling towers, some sediment accumulated in the basin during the trial (for example, compare the PVC pipe in Photos 7 and 9). However, this accumulation did not appear to be related to algae and did not possess the distinctive bright green color shown in the initial photos.

In order to provide greater resolution in assessing the effectiveness of the Solution 3000, a small section of white PVC pipe at Site E was brushed clean on Day 1 of the trial, removing the dead algae and sediment (Photo 15). As shown in Photos 16 – 18, this section remained clean for the initial 14 days, at which time the basin was vacuumed as part of its regularly scheduled maintenance. Following the cleaning process, the white pipe remained clean for the balance of the evaluation, as shown in Photos 19 - 22. The impact of discontinuing the Solution 3000 feed is shown in Photo 23, which was taken 7 days after the conclusion of the trial. Significant algae re-growth is shown in this photo (compare to Photo 22).

CONCLUSION

CDG Solution 3000, a 0.3% aqueous solution of chlorine dioxide, proved to be effective for eliminating and preventing re-growth of algae in an operating cooling tower water system. The 30-d trial was conducted under challenging conditions—nearly constant hot and sunny weather--and verifies that this product is an effective algaecide when used according to the directions on the label. It was found that the initial high level product addition completely destroyed the existing algae growth within a few hours of application and that relatively low follow-up residuals were sufficient for preventing re-growth.

PHOTO 1. Cooling tower general view.

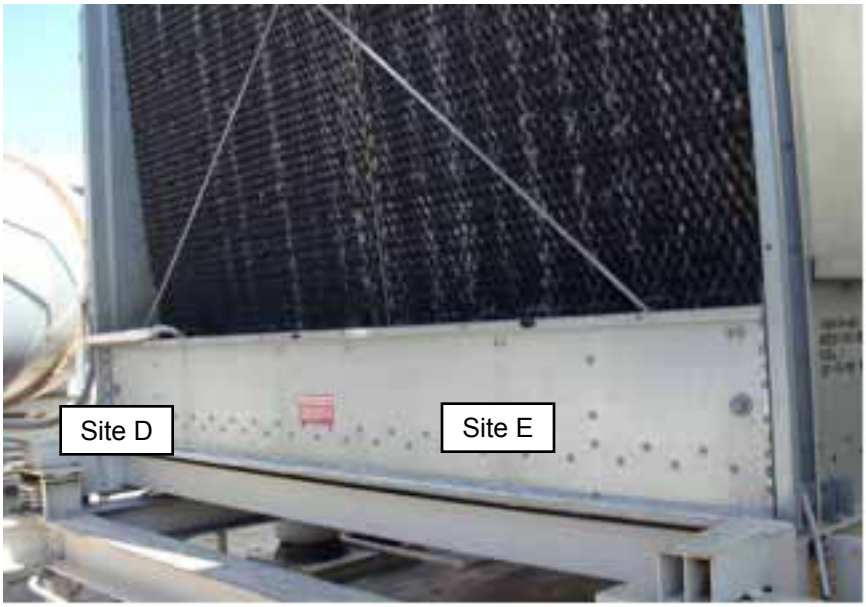

PHOTO 2. Close-up of cooling tower basin. Algae photos were taken by standing on the I-beam shown in the foreground on the left side. Site D is the far left side of this basin. Site E is in the middle.

PHOTO 3. Side/top view of cooling tower basin showing water in basin.

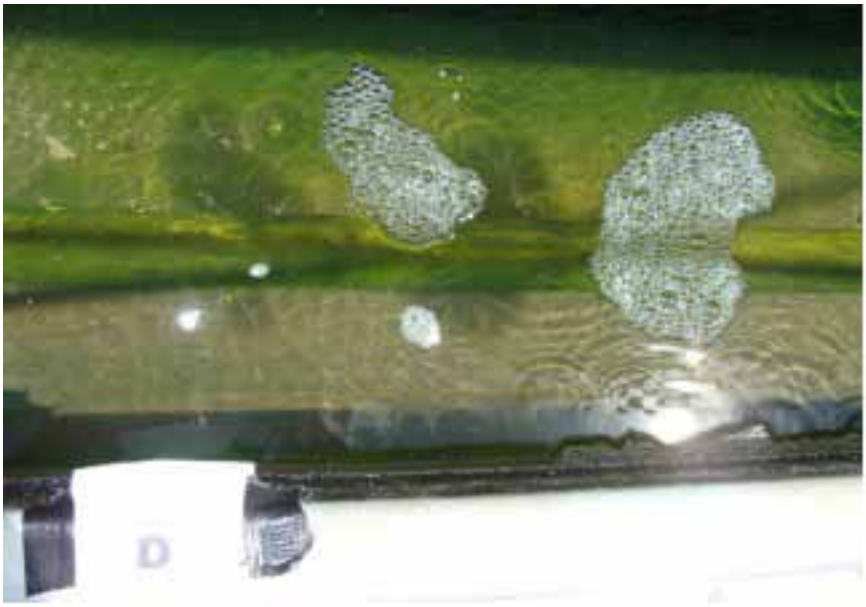

PHOTO 4. Day 1, site D. Algae in basin and coating PVC pipe prior to Solution 3000 application. Direct measurement of the algae deposit was not possible since it washes away when disturbed, due to the flow of the water.

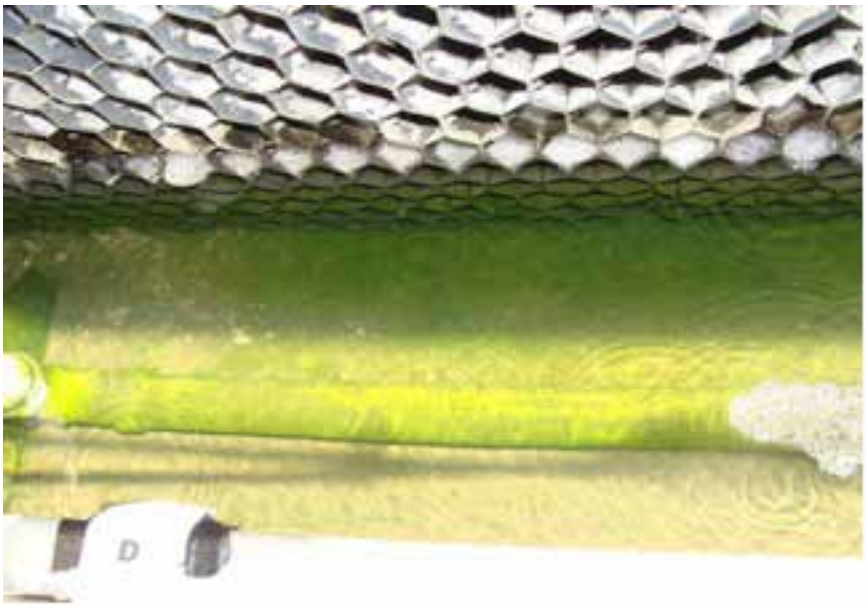

PHOTO 5. Day 1, site D. Significant algae growth in basin and coating PVC pipe prior to Solution 3000 application. This represented the “worst-case” site in the tower basin.

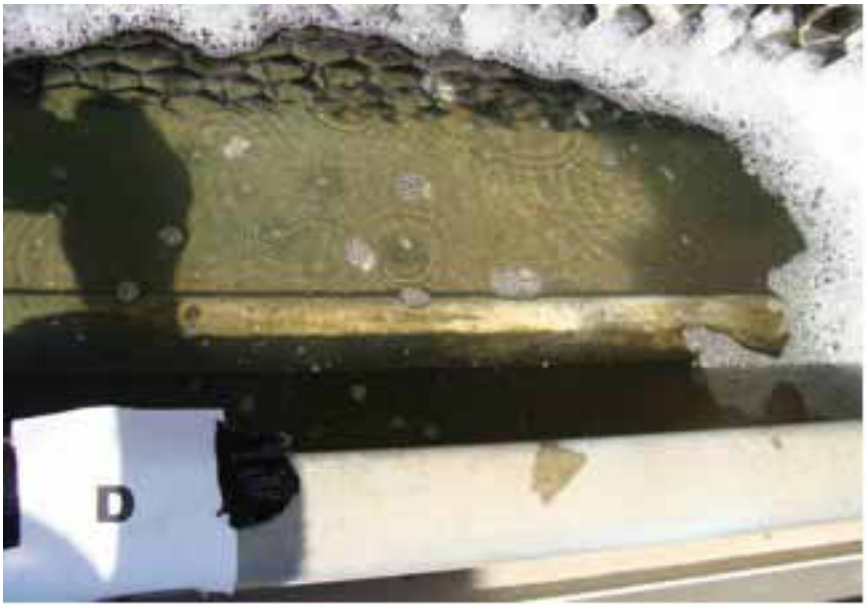

PHOTO 6. Day 1, site D. Two hours after initial 50 mg/L slug dose of CDG Solution 3000. Nearly complete destruction of the algae was achieved, as evidenced by the color changing from bright green to brown.

PHOTO 7. Day 4, site D.

PHOTO 8. Day 9, site D. Sediment accumulation in the basin is shown.

PHOTO 9. Day 14, site D.

PHOTO 10. Day 16, site D. The tower was vacuumed on day 15, as part of its regularly scheduled maintenance, removing much of the dead algae and sediment.

PHOTO 11. Day 21, site D.

PHOTO 12. Day 26, site D.

PHOTO 13. Day 30, site D. Significant re-growth was not observed at this site.

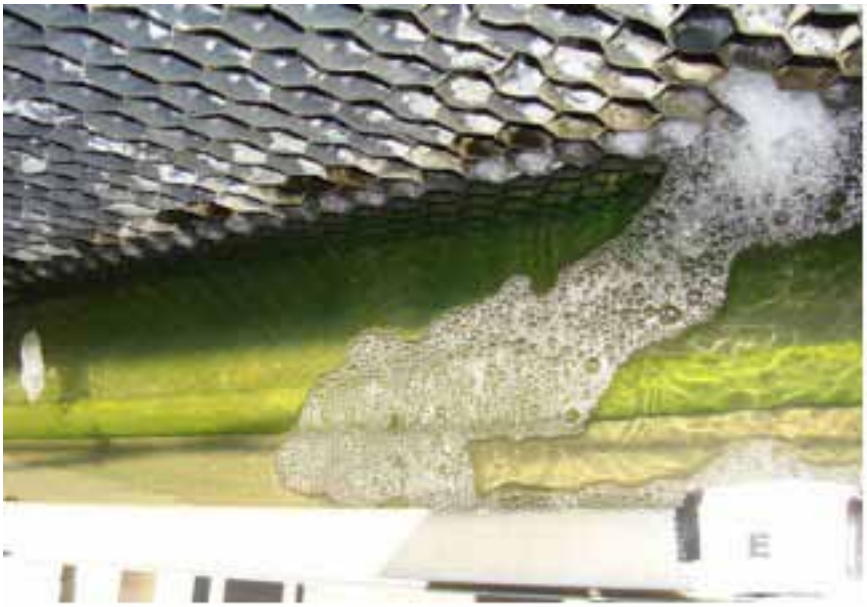

PHOTO 14. Day 1, Site E, prior to Solution 3000 application. This site was in the same basin as site D, in the middle of the basin approximately 7 feet away.

PHOTO 15. Day 1, Site E. Two hours after initial slug dose. A small section of PVC pipe was brushed clean (shown by arrow) to provide more resolution in assessing algae re-growth.

PHOTO 16. Day 4, Site E.

PHOTO 17. Day 8, Site E.

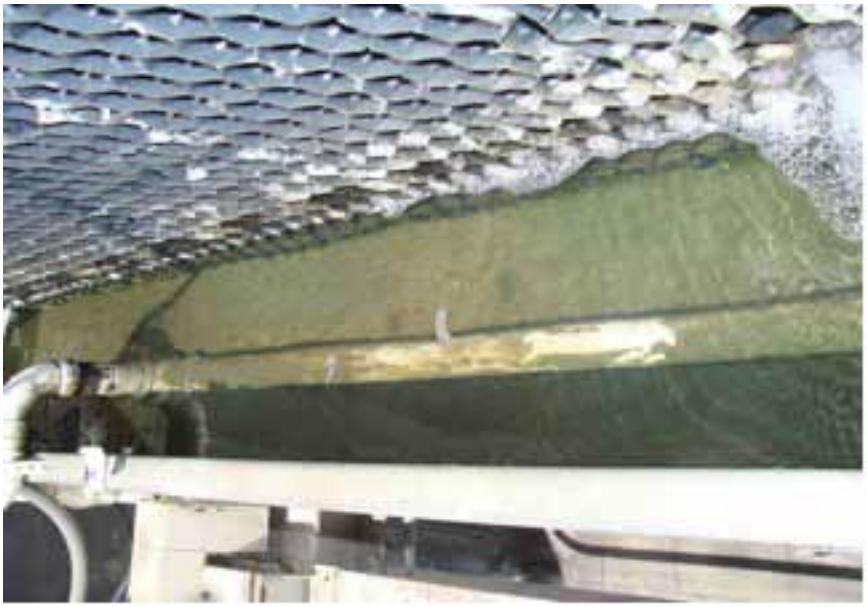

PHOTO 18. Day 13, Site E. Algae re-growth was not observed on the brushed-off section of PVC pipe.

PHOTO 19. Day 16, Site E. Basin was cleaned the prior day.

PHOTO 20. Day 22, Site E.

PHOTO 21. Day 26, Site E.

PHOTO 22. Day 30, Site E.

PHOTO 23. Site E, 7 days after Solution 3000 feed was discontinued.

ACKNOWLEDGEMENT

This evaluation was performed by Puckorius & Associates, Inc. with assistance from Dr. Dean Gregory of CDG Environmental, LLC and Mr. David Puckorius of TRS, Inc. They were helpful in the testing, application of the product and taking the photos. We also appreciate our cooling tower system owner for allowing us to perform this evaluation.

APPENDIX

1. CDG Solution 3000 MSDS
2. CDG Solution 3000 product label