Applied ATP:
Monitoring Treatment Performance – Case Histories

Richard W. Walter Jr., Ph. D.
Antimicrobial Specialists and Associates, Inc.
P.O. Box 88
Midland, MI 48640

ABSTRACT

AWT members focus on treatment of different types of water systems to improve their operation. Many treatments involve application of biocides or dispersants to control the levels of microorganisms. Historical microbiology techniques relied on different culturing techniques that took 2 to 14 days incubation prior to being able to determine if a treatment is successful or not. Utilization of ATP technology allows immediate response and determination if a treatment level has an effect or not while the field engineer is at the actual site. The engineer can then modify the treatment protocol to optimize the system immediately. This saves time and the customer money. Proper use of ATP technology and specific case histories will be discussed.

INTRODUCTION

Adenosine triphosphate (ATP) is the primary energy molecule found in all living cells whether their metabolism is aerobic or anaerobic. It is produced mainly via oxidative phosphorylation in a variety of different metabolic pathways. The ATP is then utilized by the cells to drive the enzymatic reactions that produce other chemicals and polymers (DNA, RNA, protein, phospholipids, polysaccharides, etc.) that are needed for metabolism, growth and viability of the cells. In the microbial world, if the cell's ability to produce ATP is blocked or inhibited, the available ATP in the cell will be utilized and the cell will then stop growing, go dormant and most likely die. By monitoring the levels of ATP in a solution or on surfaces, the health of the organisms in those sites can be determined. ATP monitoring can be performed in less than a minute as compared to typical microbiology techniques that take 2 to 14 to 28 days to observe growth of organisms on solid media such as nutrient agar, dip slides or Petri film or in broth dilution bottles.

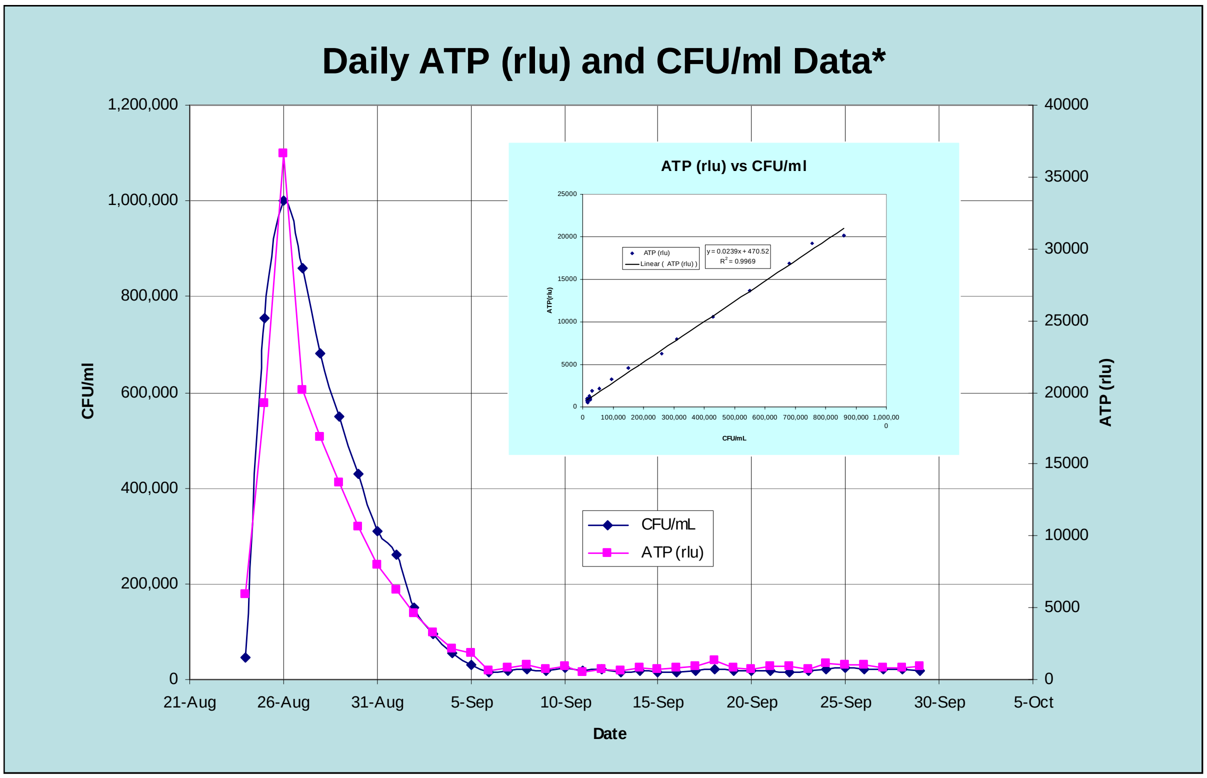
To measure the amount of ATP in a sample containing viable cells, the cells are first ruptured by addition of a lysing agent. This releases all the contents, including ATP, into solution. Additional reagents (luciferin and luciferase) are added to the solution and the amount of light produced is measured in a luminometer. The luminometer displays the number of Relative Light Units

(RLUs) for that solution. Microorganisms found on surfaces need to be scrapped or swabbed off those surfaces and then treated in a similar fashion as the solution sample.

The RLUs determined for a sample are relative to the mass of the cells in that tested sample rather than the number of cells per ml. For pure cultures in a laboratory setting or when looking at the relationship of Colony Forming Units (CFU) to RLU in a system, a good correlation can be obtained between RLU and CFU/mL (see Figure 1). In this case with one specific ATP detection system, 25 cells produced an average of 1 RLU.

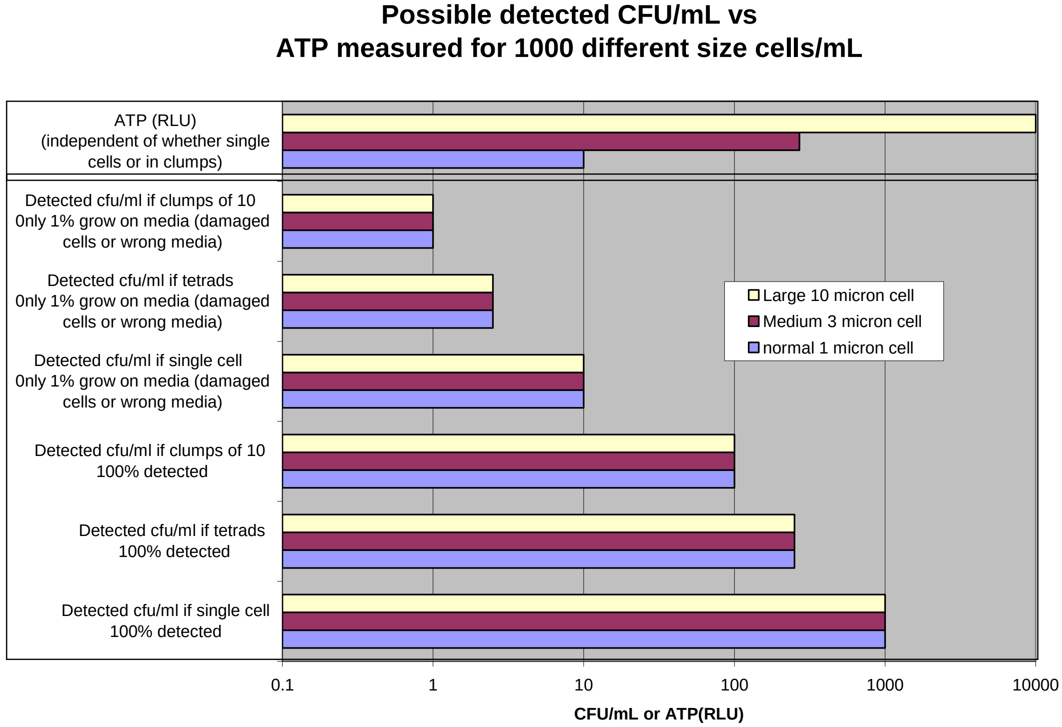
Figure 1: ATP Tracks Bacterial Counts:

Data from large cooling tower system during trial using DTEA II™ (organic deposit control chemical) addition on a daily basis.



For environmental samples that contain cells of different sizes, some of which will not grow on standard media, this correlation of RLU to cell number will vary. Larger cells such as yeast or algae will have significantly more ATP per cell than smaller bacteria such as mycobacteria. Cells that are growing in clumps in solution or un-dispersed in biofilms will yield 1 colony on a plate but have much higher levels of ATP due to the high mass of the system. Examples of these theoretical differences are shown in figure 2. Relative mass of cells will correspond better to the level of fouling either in solution or on surfaces than the actual number of detected cells. Thus ATP should be a better measure of the health of a cooling tower or other water containing system.

Figure 2: Theoretical ATP or CFU/mL determinations



Another advantage of monitoring ATP is that both the anaerobes and aerobes can be monitored at the same time. Since anaerobes as well as aerobes contain ATP, this method actually gives a better representation of the total level of contamination of a system than standard plating techniques which require different media to detect aerobes and anaerobes and often only detect 10% of the actual microorganisms present.

Results for ATP determination can be obtained in less than a minute while the field representative is at the water treatment site. The best practice to follow is to routinely track the RLUs of the bulk water or those obtained from swabbing a defined area (coupon). If there is apparent contamination, higher levels of ATP will be detected than previous measurements. The representative can immediately institute some remedial treatment such as increased biocide dosage to kill organisms in solution or addition of an organic cleaner or biodispersant to release organisms from surfaces of a system. Depending on the type of treatment, the representative can then monitor efficacy in nearly real time. If using traditional plating techniques, the representative does not know whether there is a problem or if the treatment is successful until several days later. If dealing with anaerobes, results would not be available until 28 days later using the traditional SRB bottle test.

ATP testing instruments:

For purposes of AWT, the primary features of ATP testing instruments to consider are hand held, field operable, battery powered and utilization of photomultiplier technology. Units are available from a variety of suppliers, but only 2 focus on AWT. Those that have actively marketed and sold their units for use in the industrial water treating arena are AMSA, Inc. and Bio-Trace (now 3M). Their units are both based on photomutiplier technology which is up to 800 times more sensitive than ATP meters based on photodiode technology.

CASE HISTORIES

Large Fossil Power Plant – Biodispersant treatment

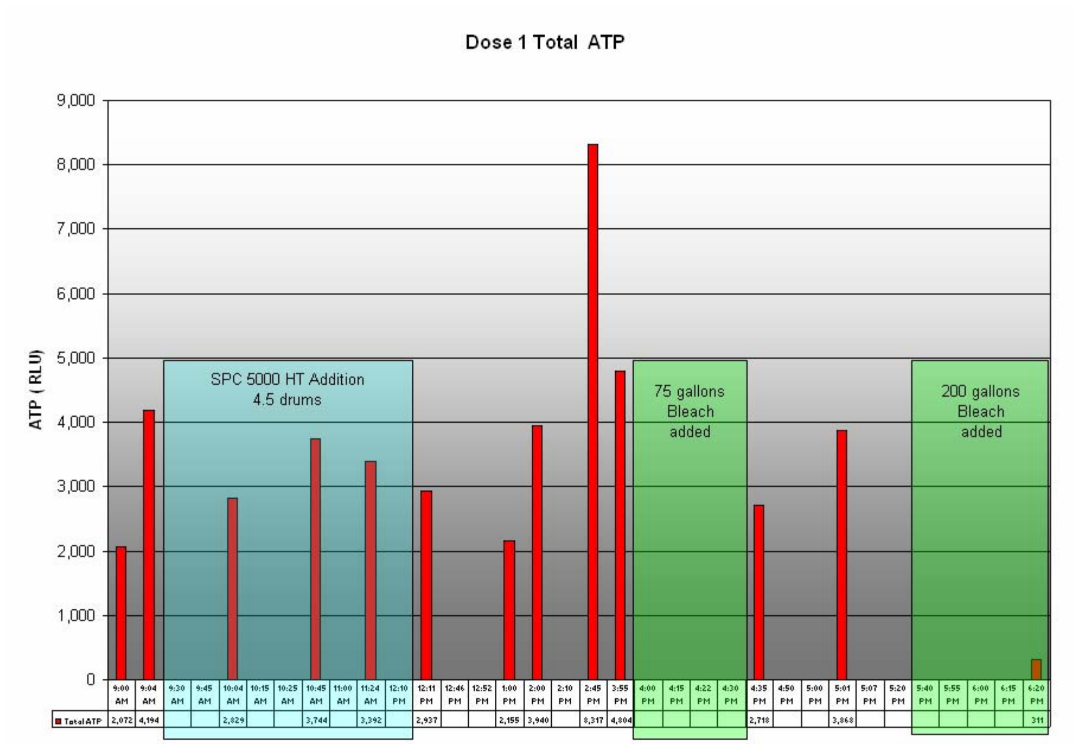
A large fossil power plant in Mexico had a severe microbiological problem. Primary treatment was chlorine which caused some yellow metal corrosion. Poor results had been obtained with bromine and non-oxidizing biocides. Treatment with DTEA II™ was initiated and monitored with ATP evaluations.

The data shown above in Figure 1 represents the combined use of ATP and plate counts to monitor a treatment. The 6 million gallon tower system was treated with 100 ppm doses of the product on a daily basis. The levels of microorganisms and ATP in solution increased for the first 3 doses as organic material was released into the bulk water. Subsequent doses resulted in less and less organic matter being released and the levels of ATP in solution decreased. After 2 weeks treatment, very little ATP was being released into solution and the dosing was reduced to a maintenance level. By using ATP (and CFU/mL in this study) the efficacy of the DTEA II™ treatment can be monitored and modified from a clean-up mode to cost saving maintenance mode. To achieve this control, personnel on site were monitoring both parameters on a daily basis. As with all control systems, the more frequent the data, the better and more consistent results.

Large 6,000,000 gallon cooling tower system – DTEA II™ and Bleach Treatment

A large 6,000,000 gallon cooling tower system with a 600,000 GPM recirculation rate, 4,000 – 4,500 GPM Blow-Down, 11,000 GPM evaporation rate and 15,500 GPM make-up rate had high TSS make-up water that caused problems with fouling and microbiological control. High levels of bleach treatment were causing increased rates of copper corrosion as well as poor microorganism control. DTEA II™ Organic Cleaner treatment was tried and monitored with ATP technology.

Figure 3: ATP monitoring of DTEA II™ and bleach treatment

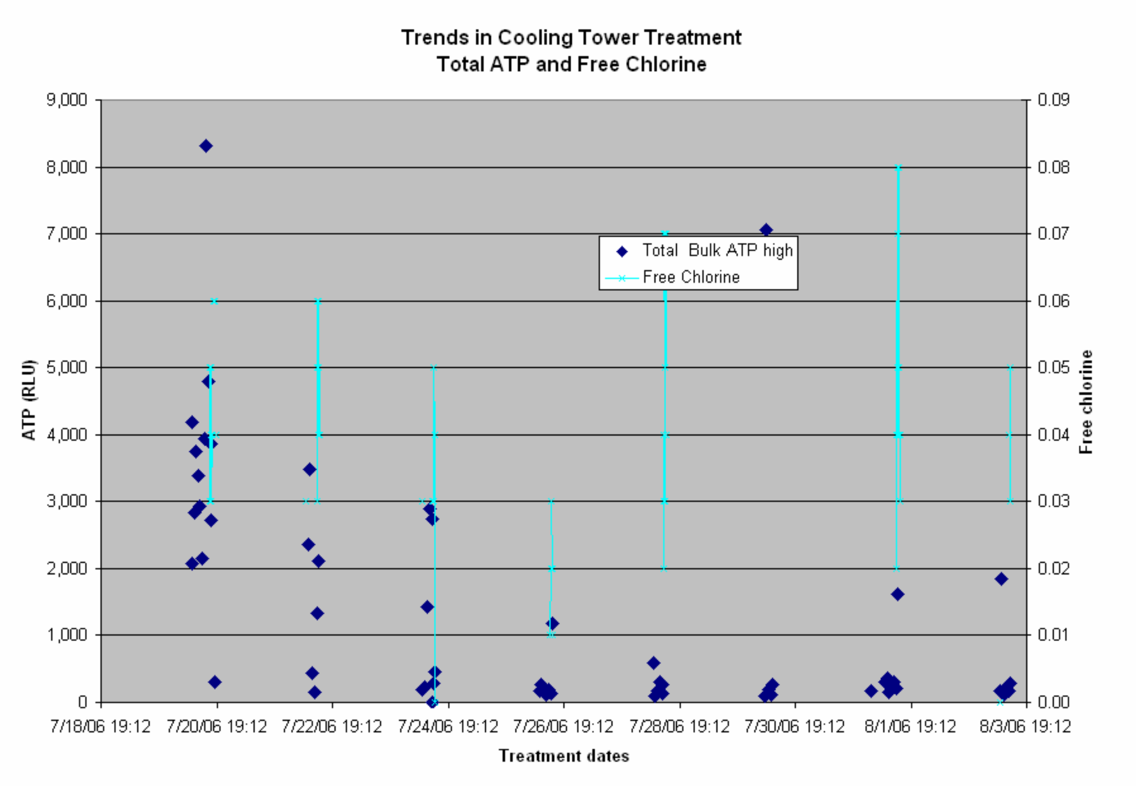


Results of the initial dose are shown in figure 3. Following initial dose of the DTEA II™ Organic Cleaner, levels of ATP in solution increased. A small dose of bleach was added with a slight decrease of ATP. Additional bleach was added to get further kill of the microorganisms in solution later that afternoon. These minor modifications of the treatment program would not have been possible with normal microorganism culturing techniques.

The rest of this trial was continued to be monitored for ATP levels. Figure 4 shows both the ATP levels on the days of the 8 doses and levels of free chlorine measured during and after those treatments and bleach addition. Levels of ATP decrease with each subsequent dose indicating that the system was getting cleaner. Levels of free chlorine increased even though dose levels were decreased during this trial from 600 – 800 gallons bleach per treatment prior to the trial to 100 to 200 galloons during the trial. Copper levels in solution decreased during this trial indicating decreased corrosion as well. Monitoring ATP allowed on line monitoring of the progress of treatment and efficacy of bleach treatment.

Two spikes of ATP were seen on the 7th and 8th dose days indicating possible clumps of biofilm were still coming out of the system.

Figure 4 : ATP and Chlorine Levels during 2 week trial

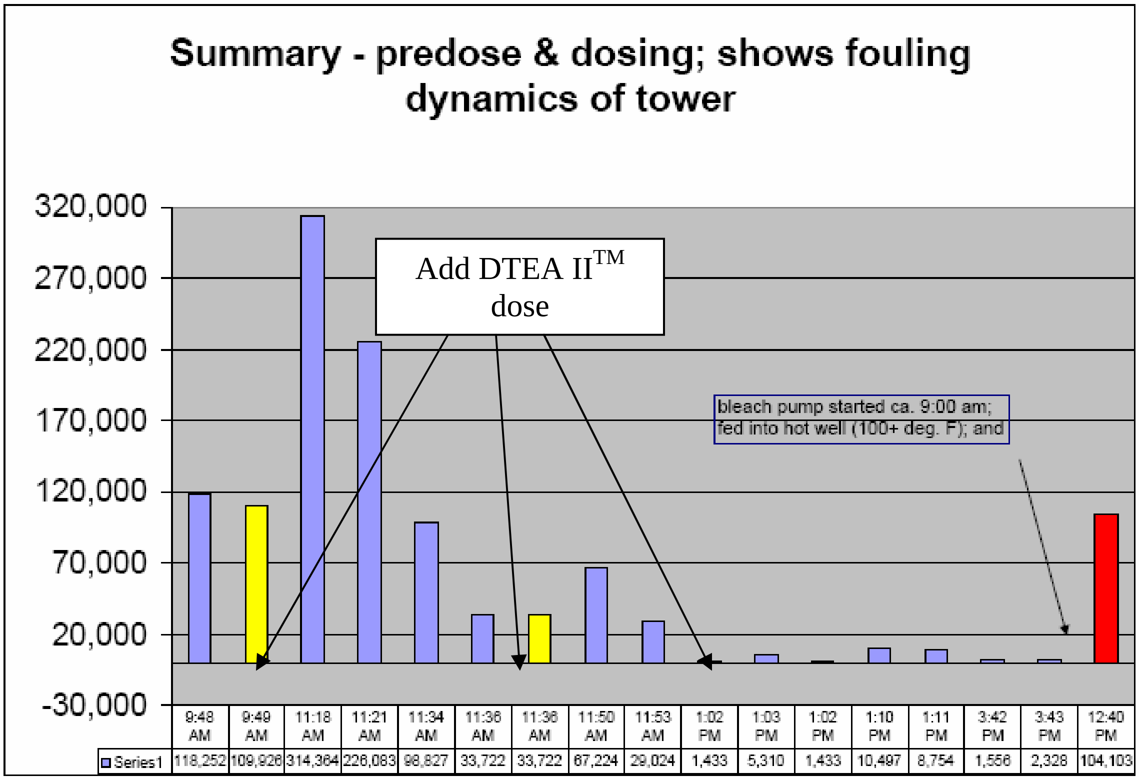


Medium Size Cooling Tower System – Emergency Clean-up

A Medium size recirculating cooling tower system containing 113,322 gallons of water, daily make-up of 86,400 gallons, a recirculation rate of 6,000 GPM, delta T of 10 degrees and was heavily fouled with many deposits of the surfaces and 500,000 CFU/mL. Prior to emergency treatment with DTEA II™ Organic Cleaner, the ATP level was 120,000 RLU. Various doses were added throughout the day and the effects were monitored by measuring ATP levels in solution. Results of this clean-up process are shown in figure 5.

Doses of DTEA II™ were added at 9:40 AM, 11:30 AM and 1:02 PM while levels of ATP were measured throughout the day. After the initial dose ATP levels rose to 320,000 and then decreased with time. An additional dose of DTEA II™ released more ATP which then decreased again. The third dose resulted in very little ATP being released into solution indicating the easily removed organic deposits had been removed. This was just a demonstration of efficacy and utility of ATP monitoring. It was not expected that this one day treatment would completely solve all problems in this system that will need additional clean-up and maintenance dosing. The final data point shows that the levels of ATP had rebounded the next day indicating that possibly the bleach treatment program may not be ideal. This trial would not have been possible without the real time monitoring made possible with ATP technology.

Figure 5: Monitoring a one day clean-up of heavily fouled system



Summary: Use of ATP as a tool in Monitoring the Health of a Water System

ATP is a chemical found in all viable organisms and measuring its level in a sample helps determine the metabolic health of the organisms in that sample. When cells die, the levels of ATP in them decrease rapidly. ATP levels in samples can be easily and rapidly measured with field operable ATP meters based on photomutiplier technology. The data obtained from these measurements and trends obtained from multiple determinations help define the metabolic health of a system as well as the efficacy of a variety of different treatment programs. Since these measurements can be obtained in minutes from sampling, overall treatment programs can be optimized rapidly.

The various studies in this paper demonstrate several applications of the utility of ATP technology to monitor treatment programs in a variety of cooling tower systems. Treatment with DTEA II™ will release organic materials including the embedded microorganisms into the bulk water. Measuring the bulk water ATP levels during a treatment allows the field engineer to determine proper treatment levels as well as demonstrate to the tower owner that the treatment is effective. Subsequent treatment with a biocide will reduce the levels of ATP in the bulk water, again helping the field engineer to optimize the treatment program. If the levels of ATP do not decrease following the biocide treatment, either the biocide is a slow acting chemical, it is being neutralized by something in the system or it is the wrong dose for the size of the system.