Allergan - Isopropyl Alcohol Emissions Removal Using A Unique Biological System

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ABSTRACT

Allergan constructed and is operating a unique biological system designed to reduce emissions of isopropyl alcohol (IPA) as well as acetone and heptane from intaocular lens manufacturing operations. The exhaust gases from the manufacturing facility are passed through a pair of wet scrubbers, in series, that allow mass transfer of the IPA from air to water. The original design called for packed towers to be used to partially biochemically oxidize the emissions. This design was changed after three months, due to fouling problems, to simply a water stripper mode of operation. Then, the water stream is passed through a fixed film bioreactor to reduce the final concentration of IPA and other emissions to less than 99% of the total inlet concentration. The inlet concentrations treated by the system ranged from 200 to 500 mg/m3 at a flow rate of 5000 cfm. On average, the system treated approximately 12 gallons per day of IPA and lesser amounts of acetone and heptane. The system is a closed system and only requires the addition of bacteria and nutrients on a periodic basis. Sludge is removed periodically.

The system was started on May 18, 1997 and went through a startup validation which was completed in December of 1997. The operational data is presented along with the method of startup and methods to overcome adverse operating conditions.

The system from two weeks after startup has maintained an IPA removal efficiency of greater than 99%. Nutrient loading and pH adjustment have been fine tuned during the startup validation period. The system has proved to be as economical as first described in a previous paper as compared to other control devices such as catalytic thermal oxidation.

INTRODUCTION

Allergan is an eye and skin disease management health care company with specialty areas including neuro-muscular disorders and retinoid therapies. The company produces both prescription and "over the counter" products on a worldwide basis.

In Anasco, Puerto Rico, Allergan has a facility that manufactures intraocular lenses. This facility uses isopropyl alcohol (IPA), acetone, and heptane as aids during the manufacturing process. In 1996, the production of the lenses was anticipated to increase by several fold over the next two years. This increase in production would require that an air emission control system be installed to handle the anticipated IPA, acetone, and heptane emissions. The predominant emission is IPA. Minor amounts of acetone and heptane are used as well.

Allergan considered catalytic thermal oxidizer treatment, vapor recovery, and biological treatment as possible treatment technologies available. Several studies have indicated that biological treatment of organic chemicals such as alcohols and ketones have been successful. (1,2,3,4,5,6,7)

Allergan tested the feasibility of using a biological treatment system for air emissions via a pilot system which was designed and constructed by Bio Alliance Corporation. The results of the pilot study were reported previously. (8)

The success of the pilot system convinced Allergan to pursue a full-scale bioscrubber control device for its manufacturing facility in Anasco, Puerto Rico. The following describes the startup method, operating conditions, and operational issues.

MATERIALS AND METHODS

The elimination of volatile compounds present in waste gases by microbial activity occurs because the volatile compounds serve as a carbon source for microbial metabolism. Thus a broad range of organic compounds can be eliminated by microbial processes. Two processes are required to produce effective microbial destruction of organic compounds in this system: 1) the organic compound needs to be mass transferred to the aqueous phase from the air phase and 2) the microbial surface area and retention time of the organic compounds must be long enough to allow the microbes time to use the organic compounds as a food source and thereby eliminate the organic compounds from the air stream.

Pilot System

The pilot system allowed for design and operating conditions to be tested before a full scale system was designed and constructed. The pilot bioscrubber system consisted of two multistaged bioscrubber columns that included packing material for microbial growth to adhere. The microbes and water were plumbed to recirculate to each bioscrubber stage. Two bioscrubber columns were used in series with the microbes and water being recirculated to two activated sludge tanks. The first activated sludge tank was aerated to keep the oxygen level high as well as to continually mix the tank contents. The second activated sludge tank was not aerated but instead allowed to settle. The contents of the second tank were pumped back to the bioscrubber columns. The pilot system was sized to be approximately 1/50th the size of the full scale system. The recirculation pumps had a range of 1 to 10 gpm at each stage of the bioscrubber columns.

The IPA was introduced into the air stream by injecting known concentrations of IPA into flasks and connecting the flasks to the main blower line feeding the bioscrubbing columns. The blower generated an airflow of 100 cfm. Two concentrations of IPA were tested: 1) 600 ppm and 2) 1,000 ppm. The conditions of the system were tested at various pumping rates. Optimization of operating temperature, gas and liquid flow rate, nutrient concentration, aeration, mass transfer were evaluated. Start up and steady state equilibrium times, microbial growth rate, and IPA removal efficiency were also determined by using the pilot bioscrubber system.

Full-Scale System

Results gathered from pilot testing were used to design a full-scale system (Figure 1). The system was installed in 1997 and made operational in May of 1997. The system consists of two packed towers which receives recirculated bioreactor water. The water sprays countercurrent to the incoming gas stream at approximately 15 to 20 gpm for each tower. The emissions from the second tower were monitored by an Enmet sensor calibrated for IPA. The sensor is checked periodically with an OVA 128 as well as with charcoal tubes.

The water is then circulated into the bioreactor where it is passed through a fixed biological film. The retention time is designed for six hours. Therefore, there are four water cycles per day through the entire system. The microbes are introduced through a collector tank along with nutrients. It took approximately two weeks to reach steady state in the system. Air is introduced into the system by a blower system that sparges air through the bioreactor. Sludge is designed to settle in an area at the end of the bioreactor cycle. Part of the sludge is recirculated and part is removed on a periodic basis.

A Horiba U-10 water quality meter is used to measure pH, conductivity, turbidity, dissolved oxygen, temperature, and salinity. Ammonia and phosphate are measured using various test kits. COD is measured with the Hach system. These were monitored daily to begin and then weekly for the ammonia and phosphate. Ammonia and phosphate were measured using various test kits. The COD was measured using the Hach system.

RESULTS AND DISCUSSION

pH/Nutrient Interaction

The nutrients added to the system included ammonia sulfate, urea, and sodium phosphate (Figures 2 and 3). The first two months of operation revealed that ammonia sulfate caused the system’s pH to drop below 5.0. Consequently, only urea was added and the pH was maintained above 7.0 (Figure 4). A pH lower than 7.0 was a good indicator that the urea level was not adequate to support the system. This is a good indicator of system performance. Phosphate concentration is not as rate limiting as urea. The measurement of ammonia concentration in the system supported these findings. Where the ammonia concentration was measured and how soon after addition of urea also affected the readings. In general, if the pH was maintained between 7.0 and 8.5, the ammonia level was adequate to sustain the bacterial population.

Dissolved Oxygen Levels

It was necessary to ensure that the dissolved oxygen (DO) level was above 3.0 mg/l (Figure 5). If the DO was less than 3.0 mg/l, it was an indication of either not enough air flow due to blower failure, air distribution problems in the bioreactor, or high turbidity. Removal of sludge was timed with increases in turbidity (Figure 6) to minimize the effects of excess sludge on DO concentrations. If the DO fell to 0.5 mg/l, the system had gone septic and major recovery efforts were required. The DO level operates on average between 5.0 mg/l and 7.0 mg/l. This appears to be dependent on the load of IPA and the nutrient levels.

Growth Rate and Start Up

During startup, bacteria and nutrients were added to the system in excessive quantities to establish the bacterial population. Several hundred pounds of ammonia sulfate, urea, and sodium phosphate were added initially and then supplemented every other day for the first two weeks. The population established itself within two weeks as was indicated in the pilot study. The bioreactor was fed IPA at low levels at first and gradually to the operating levels currently used within the manufacturing process. Foaming occurred during the startup process as the system established itself. This subsided after two weeks.

After startup, bacteria were added once per week in water soluble packets. This was done to ensure that the existing population would be supplemented with growth from new healthy cells. The nutrients were added on a weekly basis until the fine tuning of the quantity required and frequency could be established.

Packing vs. No Packing

It was always felt that packing was required to ensure efficient mass transfer of the emissions from the air phase to the water phase. The system required that the bioreactor water be used to scrub the emissions from the gas phase. The problem was how to manage biological growth on the packing material. The pilot system operated for approximately two months without having a plugging or excessive growth problem. It was therefore assumed that the full scale system would respond the in the same fashion. This did not occur. The packing gradually became excessively overgrown with bacteria to the point that an excessive pressure drop was created. This pressure caused problems such as foaming and overflowing of the bioreactor. It was attempted to clean the scrubbing towers with hydrogen peroxide and water. But this was difficult to do and not felt to be a long term solution.

The packing was removed from the first tower to determine what the efficiency of removal would be without packing (Figure 7). It was found that the packing did not add significantly to the mass transfer of emissions to the liquid phase. Therefore, the packing was removed from both towers. The efficiency of removal of emissions throughout this entire process and since that time has always been approximately 99% with some measurements that declined to 98% when the packing material was removed and slug emissions occurred at the end of the manufacturing shift. Therefore, any future installations will not incorporate packed towers for scrubbing purposes.

Sludge Production

The system has been operating at close to a steady state in regards to bacterial growth. The amount of sludge produced from this system is minimal. Turbidity is being used as the measure indicating when sludge should be removed (Figure 6). Sludge is removed when the turbidity readings at the sludge collection area in the system start to approach the scale limit of the monitoring device. This occurs approximately every two weeks. The quantity is less than one pound and extremely diluted with water. Approximately, 500 to 1000 gallons is strained through a filter and the water is returned to the system. The worry of excessive sludge production has not materialized.

Overall System Performance

The system has operated above expectations under all conditions. Even during the mechanical problems described above the system has continued to be approximately 99% efficient at emissions removal (Figure 7). The system took approximately three months to stabilize and for Allergan to feel comfortable operating. Since the beginning of September, the system has operated within its performance criteria with minimal operational input other than nutrient and bacterial addition weekly and monitoring.

System Costs

Not including the concrete pad design and construction, ducting to the system from the air emission sources, utility design and construction, and permitting/planning permits and fees, the initial cost of the system for this application was approximately $40/cfm installed. The operating costs are approximately $9/cfm/year (Table 1). The comparable costs of a catalytic thermal oxidizer ranged from approximately $60/cfm to $70/cfm initial cost installed with operating costs ranging from $18/cfm/year to $20/cfm/year based on this case study application. Solvent recovery systems such as condenser systems initial costs ranged from $112/cfm to $360/cfm based on this case study application. Therefore, the bioscrubbing system was determined to be the most economical of the types of systems considered.

CONCLUSIONS

The bioscrubber system is very reliable and becoming more and more predictable from an operational point of view. The efficiency of the system has remained high even under abnormal conditions. The production of sludge, the consumption of nutrients, odors form biological digestion have not proven to be issues in controlling this system.

The selection of this system by Allergan was thought to be, and still is today, the right choice for the application. The system has perfomed well. Allergan has considered other applications for this type of system at its other locations.

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Figure 1. Bioscrubber Schematic

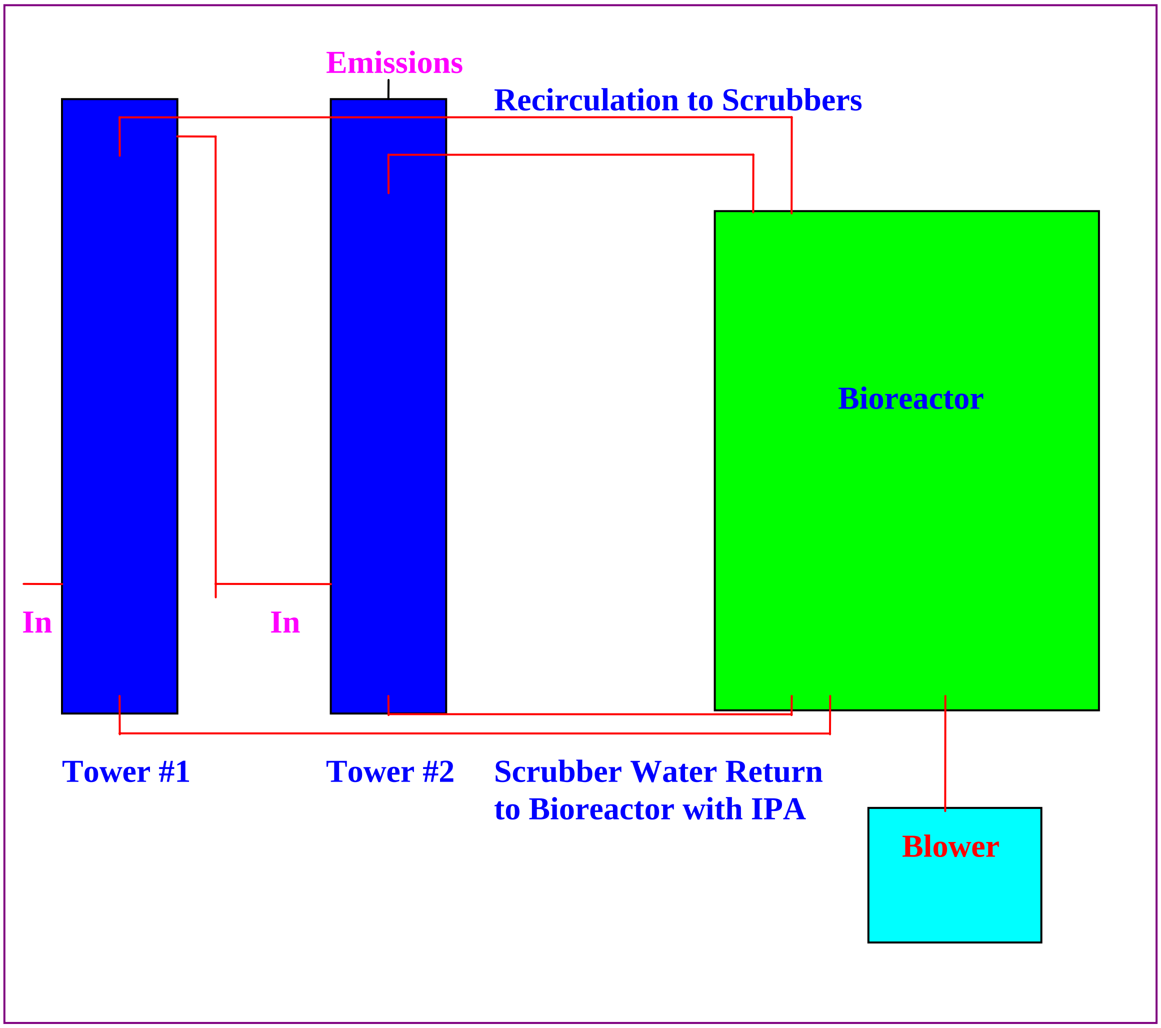


Figure 2. Ammonia Concentration Trend

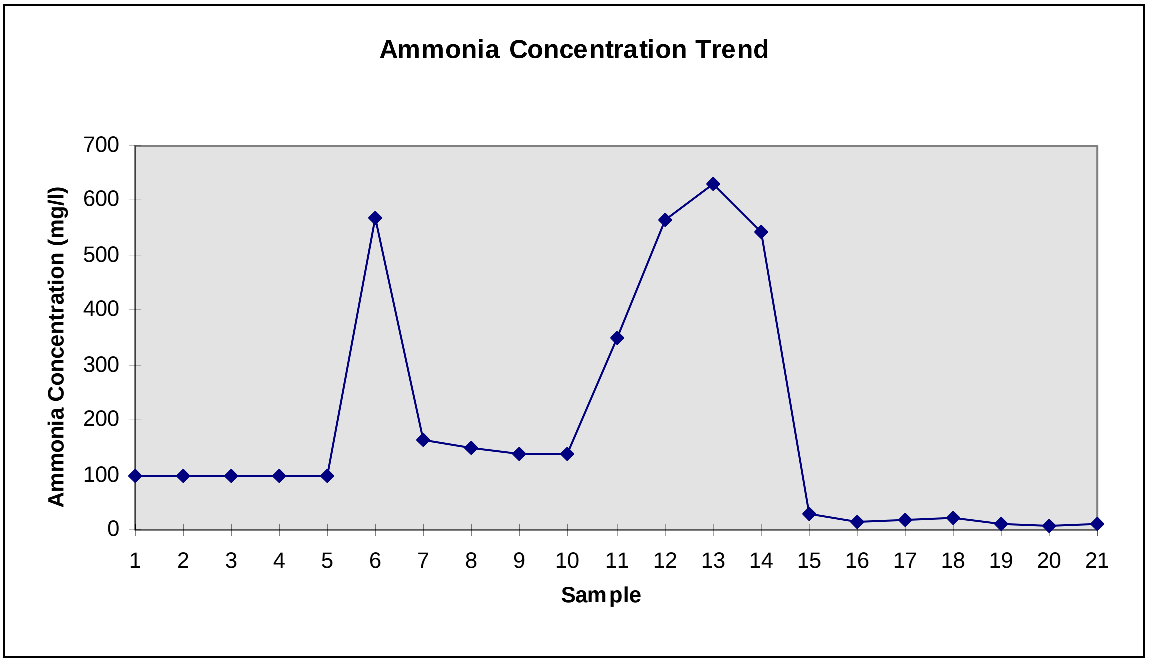


Figure 3. Phosphate Concentration Trend

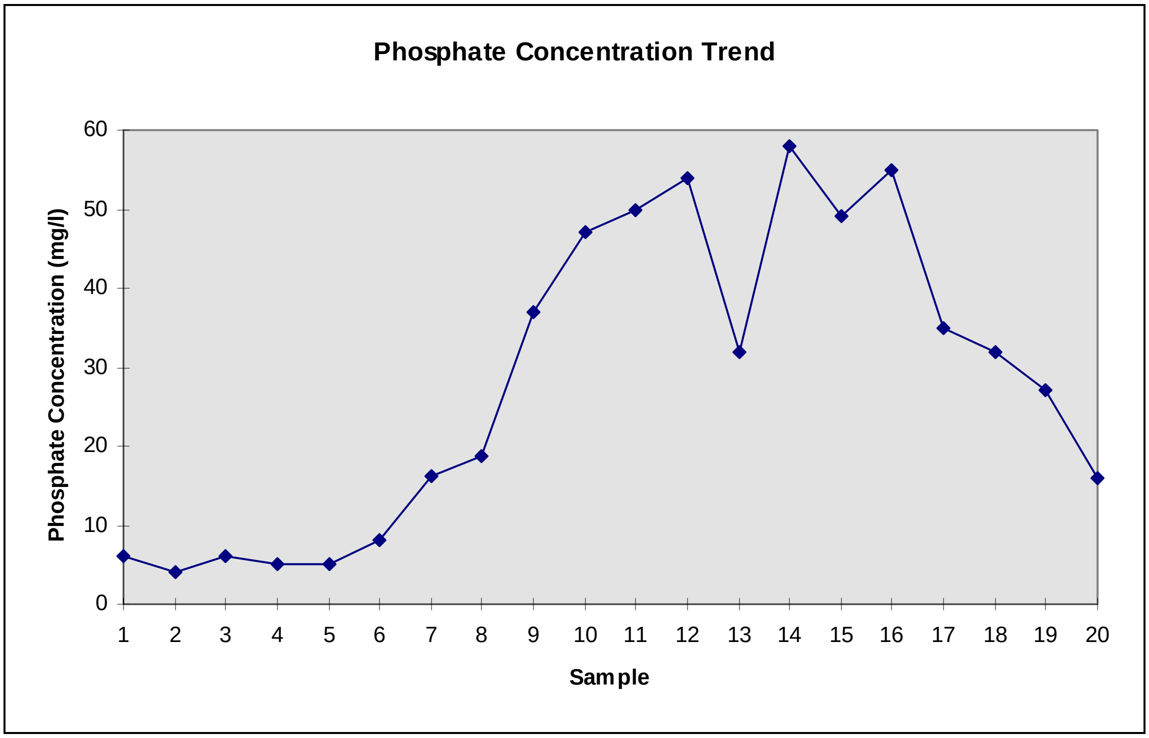


Figure 4. pH Trend

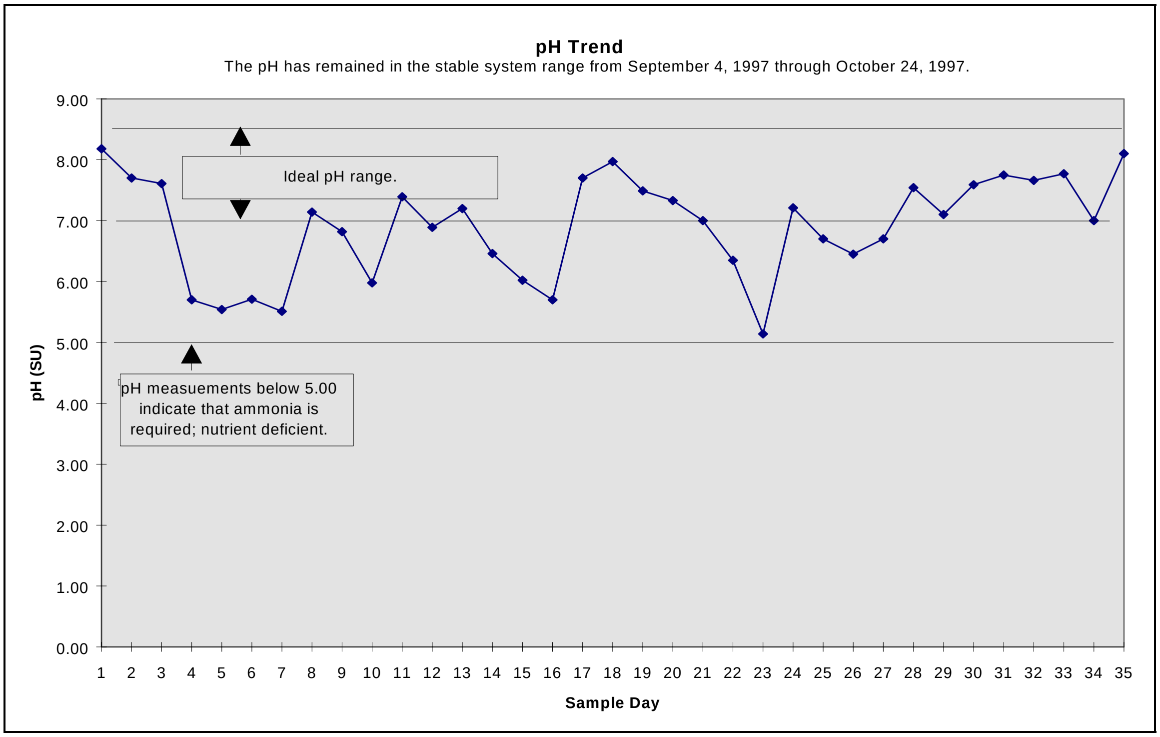


Figure 5. Dissolved Oxygen Trend

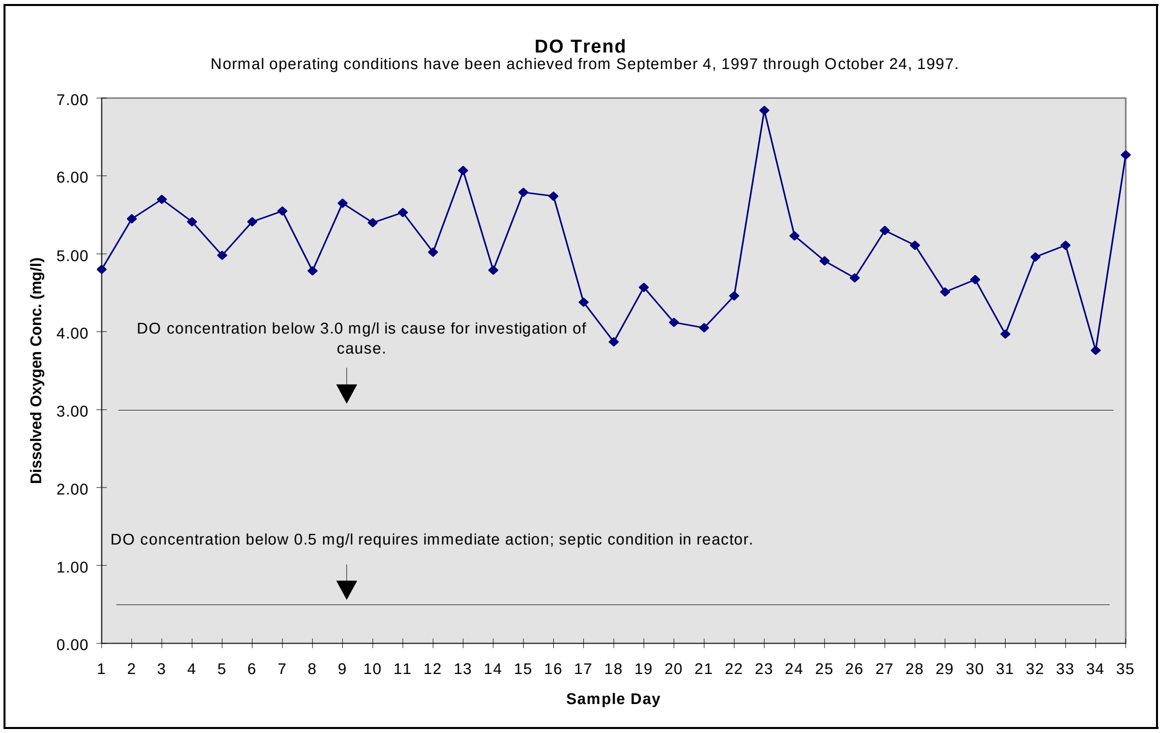


Figure 6. Turbidity Trend

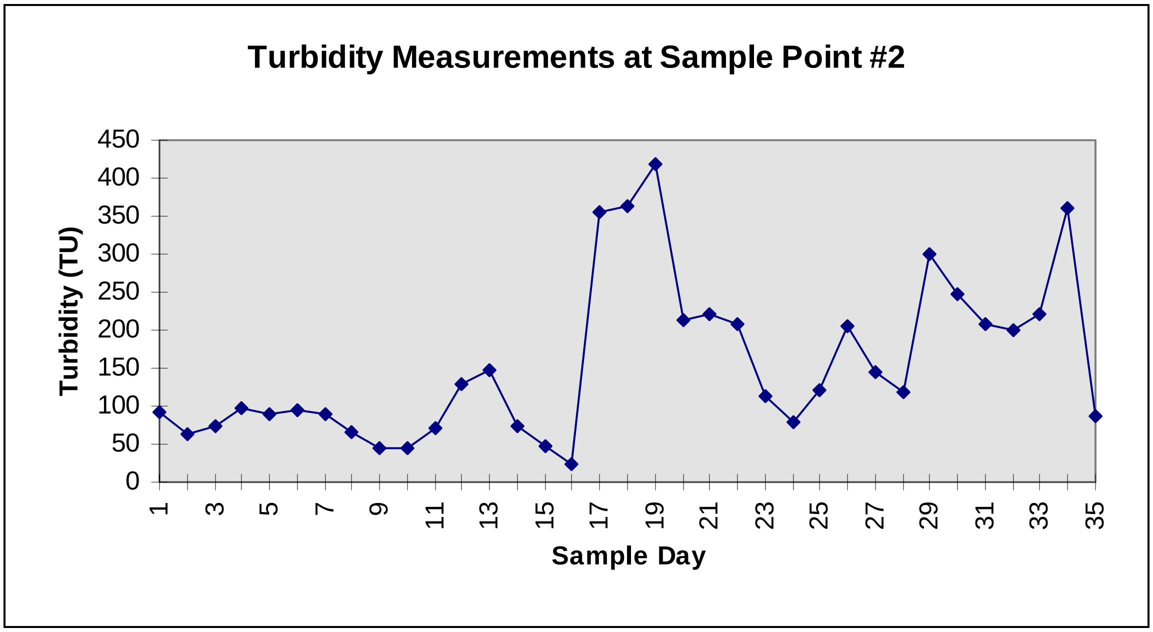
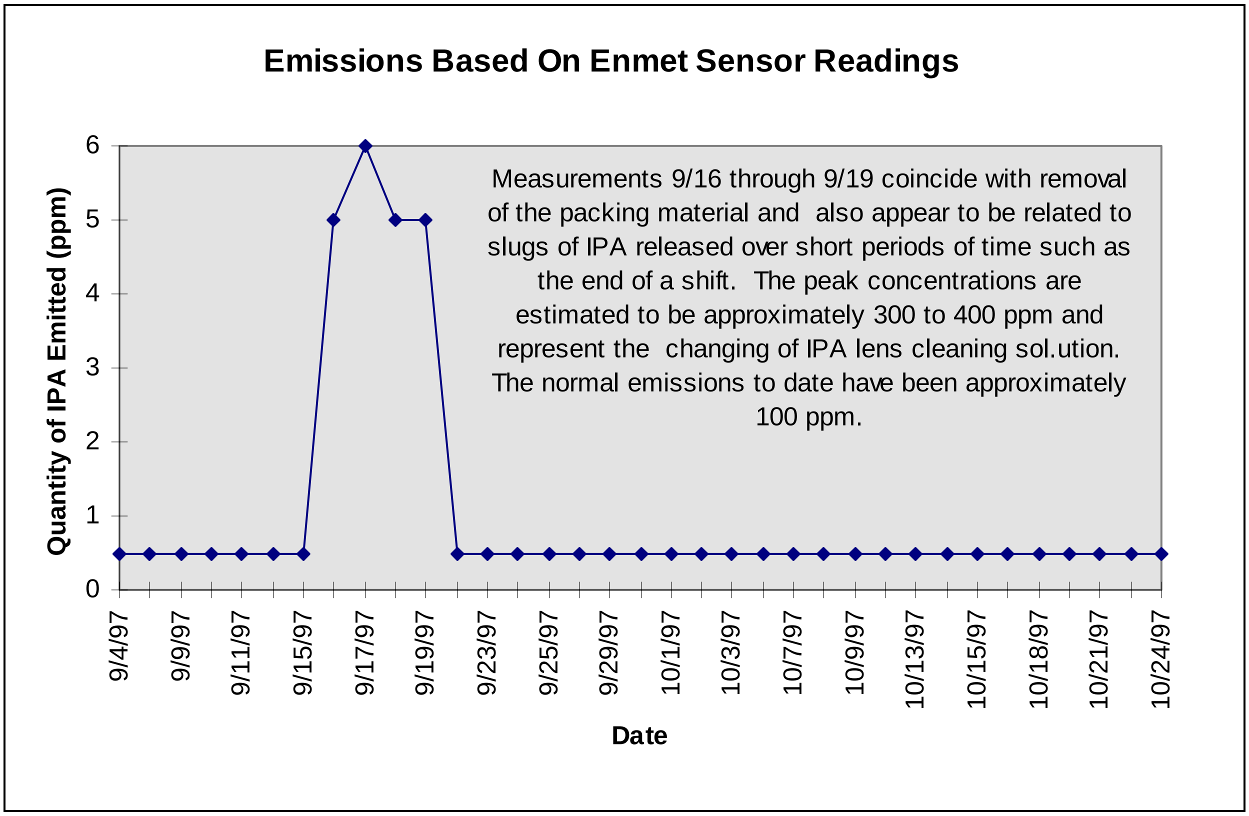

Turbidity Measurements at Sample Point #2

Figure 7. Emissions Trend


Emissions Based On Enmet Sensor Readings

Measurements 9/16 through 9/19 coincide with removal of the packing material and also appear to be related to slugs of IPA released over short periods of time such as the end of a shift. The peak concentrations are estimated to be approximately 300 to 400 ppm and represent the changing of IPA lens cleaning sol.ution. The normal emissions to date have been approximately 100 ppm.

Table 1. Annual Operating Cost Determination

Nutrient Costs			
Urea	~2,000 lbs/year	$700	
Sodium phosphate	~260 lbs/year	$50	
Microcat HX	~156 packets/year	$1,000	
Subtotal			$1,750/year
Reagents for Analytical Measurements			
Ammonia Method		$400	
Phosphate Method		$400	
Subtotal			$800/year
Electrical Costs			
4 - 1 HP motors	26,140 kwh/year		
1 - ¾ HP motor	4,901 kwh/year		
1 - 40 HP blower	261,398 kwh/year		
1 - 5 HP motor	32,675 kwh/year		
2 - 0.1 HP motors	1,307 kwh/year		
1 - 10 HP motor	65,350 kwh/year		
Subtotal	391,771 kwh/year		$39,177/year
Labor Costs			
150 hours/year	$15/hour		$2,250/year
Total Cost			**$43,977/year**
Cost per cfm/year	**@ 5,000 cfm**		**$8.79/cfm/year**