ROGER WILLIAMS UNIVERSITY

Glycol Treatment System

An Innovative Approach Using Chitin Filtration

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Executive Summary

Aircraft deicing is a necessary process which must be completed to ensure the safety of flights in cold weather locations. Many airports, small and large, use deicing fluid spray to prevent the buildup of ice on the surfaces of airplanes. Unfortunately, the fluids used to deice airplanes are harmful to the environment if not properly contained and disposed of. One of the most common fluids used by airports in cold weather locations is propylene glycol. The main concern with releasing untreated water and propylene glycol into the environment is that it increases the theoretical oxygen demand of any water sources that it enters. An increased oxygen demand of water is detrimental to the wildlife's habitat. This is why organizations, such as the Environmental Protection Agency, have imposed regulations on the effluent which can be released into waterways by airports. Although many large airports have solutions to this problem, it still remains an issue for many smaller to mid-sized airports.

This goal of this project was to research, identify, design and test a water treatment system that can be easily be implemented at smaller airports that lack the resources of larger airports. An ideal system would have a low cost, be easy to implement, and would have glycol recycling capabilities. These are factors which were considered when testing alternative filtration methods. The primary glycol filtration methods investigated in this proposal were activated carbon and chitin, a substance which is found on the exoskeletons of shellfish. In each case, the glycol becomes physically attached to the chitin and the activated carbon. After numerous experiments and an economic analysis, chitin was determined to be the best filtration medium. Chitin is an abundant substance which can easily be obtained from canneries and seafood processers. In addition to the abundance of chitin, it presents the option of glycol recovery and reuse of the shell product in other industries such as concrete production. Overall,

the use of chitin as a filter offers the possibility of an inexpensive and effective deicer filter for small and medium sized airports.

Problem Statement and Background

This report is presented by Roger Williams University. This is the first year our team has participated in the FAA Design Competition for Universities. This FAA competition engages students to create solutions to problems that exist in airports today. The competition consists of three basic categories where a main focus is chosen: Airport Operations and Maintenance, Runway Safety/Runway Incursions, and Airport Environmental Interactions. Initially, the team decided that given all of our backgrounds (Presented in Appendix J) to focus on the operations and maintenance category. After making that decision, we began the process by contacting a local airport to gain support throughout the two-semester duration of our project.

The team contacted individuals at TF Green Airport who agreed to participate with us as a mentor throughout the design process. TF Green Airport is managed and operated by the Rhode Island Airport Corporation. The Vice President of Environmental Management Systems, Brenda Pope; Manager of Engineering, Ahmed Shihadeh; and Senior Vice President of Planning Engineering and Environment, Ann Clarke were the contacts provided to us for an initial meeting. During our first meeting with our contacts, the Airport Corporation representatives requested that we consider a problem that they have recently encountered, glycol runoff into waterways. Glycol is the chemical that is used to deice aircraft before takeoff to ensure there has been no ice buildup. Until recently, there have not been any regulations regarding the chemical composition of storm runoff.

The Rhode Island DEM (Department of Environmental Management) recently issued new environmental regulations involving the use and disposal of glycol in the deicing of airplanes. For example, glycol can no longer be disposed of using the traditional storm water runoff system at T.F. Green Airport. Currently, the airport uses vacuum trucks to collect the glycol from the apron and then transport the diluted glycol to tanks on site. Preliminary proposals to address this problem have been collected by TF Green airport and most involve using a large anaerobic digestion system. Using the currently proposed system, there is a need for a 4 million gallon tank on site to store the diluted glycol. However, space is limited. At present, the Rhode Island Airport Corporation has enlisted the assistance of consultants in crafting a request for proposals that will address the construction of a system to meet the DEM's new regulations.

In light of this, we proposed to the Airport that we conceptualize and design a new system that will efficiently remove, treat and dispose of glycol while still meeting the DEM's standards. It was our goal to design a full system that could treat the glycol in conjunction with the discharged stream, thus, possibly eliminating and/or drastically decreasing the intended storage system. Ultimately, the designed system should be cost effective, achieve the goals set in the FAA competition, as well as address all challenges presented to us by the Rhode Island Airport Corporation.

There are two different types of glycol used in the deicing process, propylene glycol and ethylene glycol. Throughout this paper, our focus is specifically propylene glycol because of its use at TF Green Airport. Although propylene glycol is less toxic to human and aquatic life than ethylene, both chemicals pose serious environment challenges during the biodegradation process. The biodegradation of propylene glycol can result in a significant reduction in dissolved oxygen (DO) levels which in turn can potentially lead to massive fish kills. The glycol causes a reduction in DO levels because the chemical has a very high biological oxygen demand (BOD). New effluent guidelines recently implemented by the Rhode Island DEM and expected later this year by the EPA have forced all airports to pursue more effective storm water collection and treatment methods.

Given the basic knowledge and background of this issue, we researched systems that have been successfully tested in the past as well as pursued other, more non-traditional means of treatment. The problem we addressed involves a wide scope involving many different perspectives and alternatives available. Working with TF Green as our candidate airport and mentor, we designed a system using our objectives as a guideline. The overall goal of the project was to ensure that our solution is a viable option for both TF Green and other airports around the country.

Objectives

There were several objectives associated with this project that allowed us to obtain a viable solution. They were the following:

1. Investigate and research systems that are currently in use.
2. Acquire information and data from other systems currently in use.
3. Establish specifications for each subcategory of the system (treatment, removal, and disposal).
4. Establish specifications using T.F. Green Airport or other medium commercial sized airports as the focus of analysis.
5. Design an efficient glycol treatment, collection, removal, and disposal system.
6. Recommend steps to successfully run the most efficient system that corresponds to T.F. Green specifically.
7. Develop a model that will simulate the system using real data from previous winters.
8. Compare models to illustrate each system’s strengths and weaknesses.
9. Develop a final system to be applied to TF Green and other airports around the country.

Summary of Literature Review

EPA Regulations

Research into systems for the effective treatment and removal of glycol is particularly important because of new regulations that are being proposed by the Environmental Protection Agency (EPA) (Environmental Protection Agency, 2009). The regulations are not yet in place, but will represent a significant challenge to airports using glycol if they are passed: two sample calculations contained within the EPA's report show costs of $63.3 million and $50.7 million for a complete collection and treatment system, with an additional $2.4 million and $1.8 million in annual costs.

Discharge Limitations

Proposed EPA regulations concern two quantities: chemical oxygen demand (COD) of discharge and quantity of ammonia. COD will be governed by both a daily maximum and a weekly average, while ammonia will only be subject to a daily maximum. The specific values are found in the table below, taken from the EPA's Proposed Effluent Limitation Guidelines (Environmental Protection Agency, 2009).

Parameter	Time Period	COD	Ammonia
Limitations (mg/L)	Daily Maximum	271	14.7
	Weekly Average	154	N/A
Long-Term Average (mg/L)	All	41.0	5.24
Variability Factors	Daily	6.61	2.81
	Weekly	3.8	N/A

Figure 1. COD and Ammonia: Proposed Limitations with Long-Term Averages and Variability Factors

Environmental Impact

The discharge of untreated deicing fluid has been shown to have a number of harmful effects that the EPA's proposed regulations are intended to help alleviate (Environmental Protection Agency, 2009). A list harmful environmental impacts are identified by the EPA is presented below (Environmental Protection Agency, 2009).

- Reduction in dissolved oxygen levels in water bodies receiving deicing storm waters
- Increased nutrient concentrations in water bodies receiving deicing storm waters
- Fish kills downstream of deicing storm water outflow
- Impact to aquatic ecosystems downstream of deicing storm water outfalls, including reductions in organism abundance and diversity or elimination of the aquatic community
- Contamination of groundwater and surface drinking water resources
- Aesthetic impacts to surface waters, including foaming, noxious odors, and discoloration
- Complaints of headaches and nausea by people exposed to deicing storm water odors

Reduction in dissolved oxygen levels is a fairly common problem associated with the discharge of chemicals. It is also a problem of great concern, as a consistently lower dissolved oxygen level not only harms plant and animal life but can cause shifts in local ecosystems over the long term.

Case Studies

As a component of an effective design process, it is important to consider the ways in which the specific problem has been addressed in the past. Such an analysis reveals the designs strengths as well as any inherent shortcomings. This information can then be used to guide the selection of design alternatives for further evaluation.

In reviewing glycol treatment and removal systems that are currently in place, two systems emerged as particularly successful designs. These systems are the anaerobic digestion system in place at Albany International Airport and the engineered wetlands system in place at Buffalo Niagara International Airport. Both systems are described below, as well as the specific challenges that were addressed.

Albany International Airport

An excellent study in the design and implementation of glycol treatment/removal systems in airports is one implemented by Albany International Airport (Engineer, 2002). In the late 1980's, an order was issued to Albany International by the New York State Department of Environmental Conservation requiring that they stop discharging glycol-laden wastewater into a nearby creek. Due to time constraints posed by the order, the only solution that could then be implemented was a collection system that required transport to a 3rd party treatment facility. Collection was performed by a trench drainage system around the gate areas. Once collected, the wastewater was pumped into a large tank and two lagoons for storage until it could be disposed. Unfortunately, this system proved to be expensive and thus undesirable. Later, when there was time to investigate a more complete solution, Albany International solicited collaboration from a number of different groups. This collaboration resulted in a very successful and beneficial system that has since won a number of awards and in many cases is viewed as a model solution for airports everywhere facing similar challenges.

Albany International's current glycol treatment system utilizes a two-part anaerobic digestion system to treat the approximately 30 million gallons of glycol-laden wastewater generated over approximately 5 months of the year in a 12 month long cycle (CBS6, 2009). The second component of the digestion, added in 2001, utilizes a reactor 10 feet in diameter and 22 feet tall with a sand bed filter, as well as 95 percent pure oxygen that is used in the process[1]. This system has a number of noteworthy characteristics. Perhaps its most relevant characteristic is its savings: the system eliminated the need for 3rd party treatment of the glycol wastewater, which was costing Albany International over $1,000,000 per year. Additionally, Albany International is able to use the methane gas generated as a byproduct of the anaerobic digestion to heat two of the buildings on-site during the deicing. The system as a whole is able to eliminate the need for about 400 gallons of oil a day (CBS6, 2009). Albany International is further able to use the effluent wastewater for irrigation purposes during warmer months, once again cutting costs (CBS6, 2009).

Despite the enormous savings capacity, the system has other noteworthy characteristics. First and foremost is its capability to reduce the concentration of glycol in the wastewater by an incredible 99.99%. Remarkably, this results in water that meets not only discharge standards but also drinking water standards. Also, there is a significant quantity of methane gas remaining after heating both the anaerobic reactors and the two buildings. Albany International is investigating alternate uses for this methane, such as providing electricity. The system even allowed enhancements to be made to Albany's irrigation system, which resulted in greener and healthier grass.

Buffalo Niagara International Airport

Another successful design currently implemented is that at Buffalo (NY) Niagara International Airport (Bernos, 2009). In a situation similar to that faced by Albany International, the Niagara Frontier Transportation Authority (NFTA) was issued an order of consent by the Department of Environmental Conservation in 1999. An order of consent is defined as a voluntary agreement between two or more parties in order to resolve a dispute. Like Albany, Buffalo Niagara was forced to resort to third party treatment until a more permanent solution could be implemented. The solution they ultimately chose was one utilizing four underground football-field-sized beds 1.5 meters deep and lined with a high density polyethylene material. The beds each contain a series of aeration tubes that have been topped with substances including gravel, mulch, and plantings, which act as natural filters in a system known as engineered wetlands.

As with Albany's anaerobic digestion system, there are a number of benefits to the system chosen by the NFTA. As with Albany, Buffalo Niagara's on-site treatment proved to be significantly more cost efficient than to transport to a 3rd party treatment facility. The approach has also been heralded by many as a breakthrough in terms of the environmentally friendly nature of the system. Furthermore, the system is capable of a 95% reduction in glycol concentration in only two to four days, averaging 2 million gallons per day (Engineers, 2009). The beds can also be drained in the warmer months and used to store excess storm water, which is a benefit to flood prevention. Finally, since the wastewater and treatment occurs underground, the system is said not to attract additional birds, which tend to be problematic in day-to-day operations at an airport.

While there are a number of benefits to the engineered wetlands approach, NFTA also encountered some complications with the implementation of their system. The primary complication arose from the collection of wastewater and its transport to the engineered wetlands. A number of options were considered, such as a centralization of deicing operations and vacuum sweeping at the gates. In the end, it was decided to create a storm water collection system that delivered the wastewater to off-site engineered wetlands. Even so, there were still problems to be solved. The first flow flushes resulted in nearly 4 million gallons of wastewater that needed to be treated, which was a volume the system simply wasn't meant to handle. The airport concluded that an existing underground storage system on-site could store the flush until it could be treated. Even with this additional storage however, outfall was still exceeding state regulations regarding the culvert leading to the city's storm water system. Again, multiple options were considered. This included diversion of water flow upstream of the treatment system directly to the wetlands, the creation of a detention area around the wetlands by means of a berm, and converting the existing glycol collection system into a storm water retention system. The option chosen, however, was the creation of a surface area at a low point on airport property, which was felt to be best for hydraulic considerations.

Problem Solving Approach

An important aspect of airport maintenance and operations is the use of anti icing agents in the winter to keep the aircrafts free of ice. According to an article published by the FAA in regard to ice on the surfaces of an aircraft, they state: "The safest approach is to clear the entire airplane of all frozen contamination" (Pellicano, 2009). Based on the requirements of the FAA, as well as the needs of T.F. Green Airport, a series of anti icing fluid disposal methods were evaluated. The methods included consideration of T.F. Green's space requirements, as well as regulations imposed by the Rhode Island Department of Environmental Management (DEM). The goal of the Rhode Island DEM is to reduce the release of organics (e.g. Propylene glycol) into waterways/rivers as these chemicals reduce the dissolved oxygen content in water, thus adversely affecting the wildlife (Department of Environmental, 2009). With these objectives in mind, alternative disposal methods were considered.

The first meeting with airport officials at T.F. Green Airport in October 2009 served as a guideline for what would be required of a new system for glycol disposal. We learned that an appropriate system should require minimal human resources or maintenance, and should be easily incorporated into the current airport layout. Upon understanding the problem at hand, the group decided that an ideal solution would be to collect the glycol runoff water, treat the runoff so the glycol concentration was an acceptable value, then release the treated water back into the environment. To determine a solution for this task, additional airports that faced similar challenges were contacted for evaluation of our proposed design alternatives and feedback on our design process. Initial ideas for a solution were derived from currently implemented methods of glycol runoff treatment at airports. Anaerobic digestion and aeration fields are two treatment methods currently in use at various airports in the United States.

To gain more information about the needs of airports for new methods of glycol treatment, a survey was created using Survey Monkey by the Roger Williams University team. Working with the American Association of Airport Executives (AAAE) the survey was distributed to a representative of operations and maintenance from each of the more than thousand airports affiliated with AAAE. The AAAE is an organization divided into regional branches based on geographical location. The organization as a whole serves to aid in the solving of airport development and operational problems. A copy of the survey distributed to airport representatives can be found in Appendix G. The survey asked questions such as what type of deicing/anti icing methods were implemented at the respective airport and what methods were used to collect/treat the glycol runoff. Based on these results, experts in different scientific areas were contacted to collaborate with the Roger Williams University team in identifying alternative design solutions.

Results of the Survey

When polling the airport executives, our goal was to cover all bases with regards to information that could possibly be needed when designing the system. The results that we obtained from the survey helped us understand how airports across the nation are treating their deicing runoff. Although the response rate was low, we were still provided with important background information with respect to moving forward with our project. When asked what type of deicing method was used, 75% of responders use propylene glycol while only 25% use ethylene glycol. Regarding the collection of ADF (aircraft deicing fluid), 50% of the respondents do not collect while 50% use in ground piping. Airports that do collect the ADF runoff typically treat using both aerobic and anaerobic digestion or pumping the collected runoff to a waste water treatment plant. Additional comments were provided by each responding individual that allowed for additional insight into our design challenge. Overall, the survey of the airport executives was successful, though not as wide cast as originally planned.

Professor Input

The first contact we identified was with Dr. Stephen O'Shea, a chemistry professor at Roger Williams University. In our research, we found that chitin, a substance found on sea shells and shellfish had been used to collect molecules similar in structure to glycol. Dr. O'Shea had completed previous research in this area and oversaw all of the experimental design and procedures. His previous research presented an interesting concept that the group decided to further investigate. The second expert contacted was Dr. Janet Baldwin, PE of the Roger Williams University School of Engineering. Dr. Baldwin's field of study is environmental engineering. Dr. Baldwin expanded on another design alternative we were considering involving anaerobic digestion. There are many anaerobic digestion approaches that have significantly smaller residence times than the methods employed at several major airports including the Albany airport. Additionally, Dr. Baldwin suggested testing activated carbon as a means of removing glycol from water. Activated carbon would theoretically work in the same manner as chitin, as the glycol molecules would adhere to the substance. With these alternative methods considered, experiments were conducted to determine the best approach for designing the new system.

Design Approach

Following the formulation and consideration of all possible design alternatives, the group determined that it would implement either the use of chitin or activated carbon. Following this decision, the group ordered its materials and tested whether chitin or activated carbon was a more efficient glycol removal substance. This analysis was the first step in moving to a full system design. The goals of the experiments were to determine the effectiveness of how well chitin and activated carbon removed varying concentrations (between 2.5 to 10 percent) of glycol from water. The experimental results will be discussed in greater detail in the experiment section of the paper. In addition, the group also researched alternative designs for anaerobic digestion taking into consideration the ease of implementation at currently functional airports. In addition to performance factors, a cost-benefit analysis was conducted on both alternatives. The goal was to determine which method was most effective and to weigh the effectiveness with the cost and ease of implementation.

Although the primary considerations for application in the system design were the use of either chitin or activated carbon, alternate forms of anaerobic digestion were evaluated for implementation. As stated previously, a very successful implementation of anaerobic digestion to remove glycol concentration from runoff water is used in Albany International Airport. The millions of gallons of water/glycol effluent are digested over the course of a year, due to the long residence time of the digester. Although there are examples of anaerobic digesters that have significantly shorter residence times (such as 1 to 2 weeks) thus requiring smaller storage tanks, this concept is not necessarily more viable than the large tanks with longer residence times. For example, a system which functions year round provides the nutrients for the microorganisms within to survive for the entire duration. If the residence time for a system was for example, one week, then nutrients would need to be provided to keep the microorganisms alive for the entire year. In this case, the long residence time and tank size is beneficial to the system. Again, the lack of space for large storage tanks at T.F. Green Airport and many other similar sized airports across the country is why anaerobic digestion as a method for treatment method was ruled out.

Technical Aspects of the Proposed Design

The overall goal of this proposal was to design a system which would remove a satisfactory concentration of glycol from precipitation runoff at airports. In addition to the primary goal of glycol removal, a secondary goal of the design was to create a system that could be implemented into preexisting airport layouts at minimum cost. The current system of glycol collection at T.F. Green airport is to cover the storm water drains, and to use vacuum trucks to collect the glycol laden water. Once collected by the trucks, the glycol/water mixture is then transported to a storage area on airport property (Complete Final City Comments, 2006). If the concentration of the glycol in the water is more than 3%, than the mixture is stored in a 20,000 gallon tank until it can be disposed of.

Factors considered when creating the final design, in addition to satisfactory glycol removal performance, included incorporation into the current drainage system at the airport and minimizing manual involvement in the process. The main component of the system is a basin which would contain the chitin. This basin would be in line with current storm water pipes so that the water passing through the system would be filtered out by the chitin. The filtered water would then continue on in the system where it would be released into the environment.

The physical characteristics of propylene glycol allow it to be captured by the chitin. Propylene glycol is a hydrocarbon which is completely miscible in water. The chemical structure of the propylene glycol causes it to adhere to the chitin, which in turn results in water which can be safely released into the environment. The current drainage system at T.F. Green airport releases storm water runoff into a nearby brook when glycol is not used to deice airplanes. As stated previously, when deicer is used, storm water is collected for disposal with vacuum trucks. With the chitin system, collection would not be necessary and the drainage system would be allowed to function year round.

Treatment System Operation

The method of treatment designated for implementation in this design was the use of chitin as a filtration medium. In order to save on installation and piping costs, this proposal aims at using the current drainage system in place at T.F. Green as a foundation for the treatment system. Currently, these drains collect runoff storm water throughout the months which deicing fluid is not used. When deicing fluid is used, the drains are plugged up, and vacuum trucks then collect the water laden with deicing fluid. This proposal aims at removing the need for vacuum trucks and allowing the water to drain year round. Refer to Appendix I for a satellite image of TF Green Airport with an overlay of drainage system and potential treatment facility location.

The primary concept of this system is to link a treatment system with the current piping system at T.F Green that will contain the glycol contaminated water. The entire system will consist of two 65,000 gallon tanks, one of which will be for water storage, and the other will be for water treatment. See Figure 2 below for the full operational flow chart and Appendix H for a full size version of the flow chart. Upon draining into the pipe, water will either be diverted into a nearby stream if free of glycol; otherwise it will pass through a series of filters to remove any solids which are possibly in the water. Once basic solid filtration occurs, the water will then pass through the storage tank and into the treatment tank. Contaminated water will continue to be added into the treatment tank until it reaches maximum capacity. At the point when the treatment tank is full, a valve between the storage and treatment tank will be closed. At this point the treatment process will begin, as the chitin and the glycol/water solution is mixed. This mixing will occur for 24 hours until the purified water can be released into the environment. The storage tank acts as a safety feature for the system as it contains any contaminated water that is produced while the treatment process is occurring.

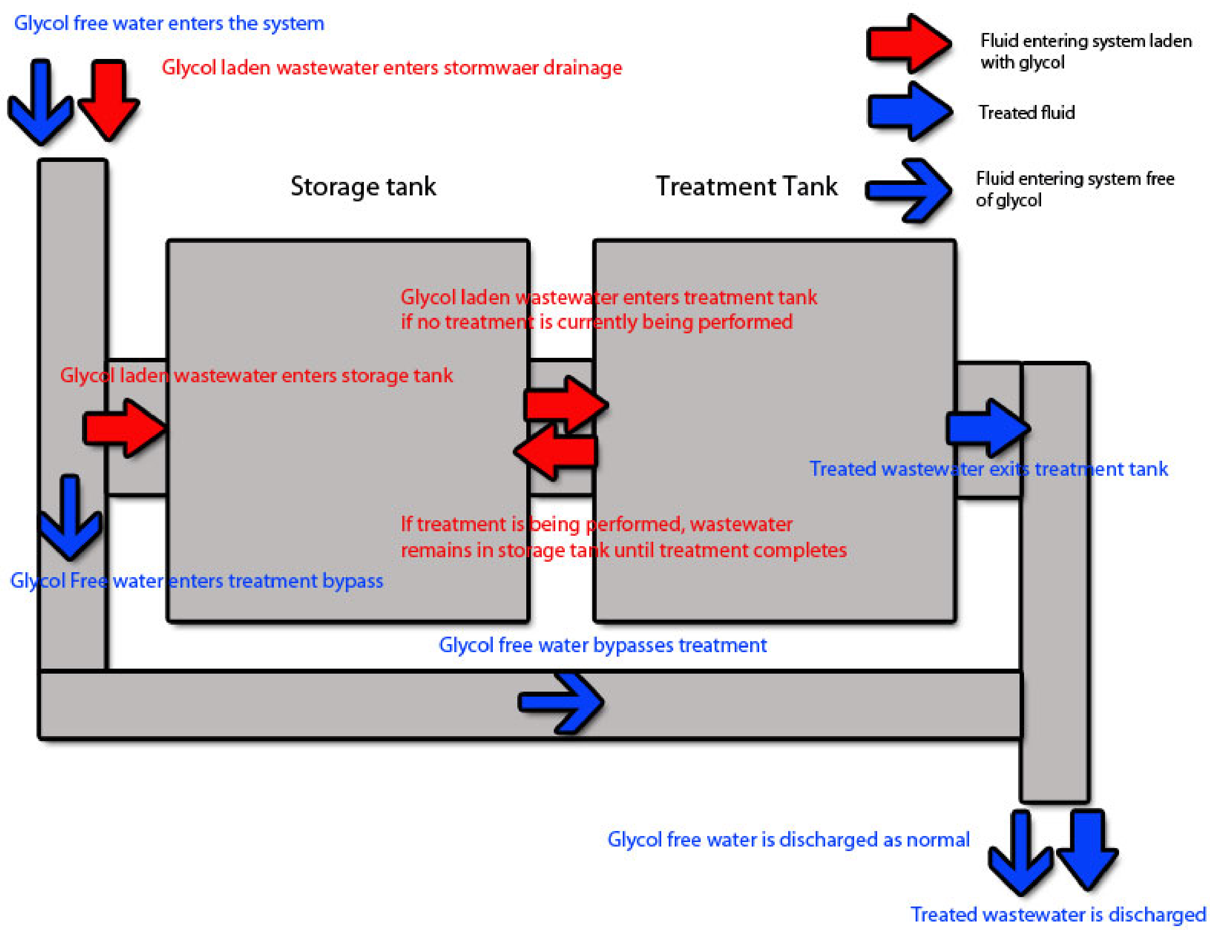

Figure 2. Process Flow Chart

System Sizing

Due to a retention time of one day for treatment, minimization of storage requires that a day's worth of rainfall and deicing fluid captured must be capable of undergoing treatment at one time. During this treatment, any additional rainwater and deicing fluid must be captured and stored for future treatment, necessitating the capacity to store an additional day's worth of rainfall and deicing fluid. The highest monthly average rainfall for the Providence, RI area is 4.4 inches. Assuming 2 inches of rainfall over a two day period on a 2 acre apron, 108,000 gallons of rainwater would need to be stored. Adding to this an estimated 1,000 gallons of deicing fluid per day and the necessary 1,100 gallons of crushed chitin, a 130,000 gallon total storage capacity allows for an approximate 17% factor of safety. This would be split into a 65,000 gallon storage tank and a 65,000 treatment tank.

Rainfall per 2 days	Apron size	Initial Capacity	Factor of Safety	Final Storage capacity
2 in	2 acre	108,000 gallons	17%	130,000 gallons

Table 1. System Sizing

System Details

The proposed design aims at removing the need to treat non-contaminated water, as the valves control the flow direction of the water. As per the design aspect of the proposal, it will require approximately 5.5 cubic yards of chitin to reduce the glycol concentration of 1,000 gallons of deicing fluid. This was calculated from a ratio of 30g of chitin to 50mL of deicing fluid observed during experimentation. The chitin will be placed only in the treatment tank, which will be removed after every batch of 65,000 gallons is treated.

Inside the treatment tank will be a large mesh net, which will be lifted via machine (such a backhoe) and unloaded onto a truck for transportation. The used chitin will then be processed for glycol recovery and for selling to outside companies. It is estimated the 50 percent of the glycol will be recoverable from the used chitin by shaking it to release the physically attached molecules. This used product can then be sold to an outside company for reprocessing. Additionally, the used chitin is also of use to many outside industries. One example of an industry which could make use of the chitin would be a concrete industry, which could include it in their mixtures. It is estimated that the used chitin could be sold for half of its purchase value. This resale aspect of the proposal saves half of the cost of purchasing the chitin to function the system.

Overall, the entire design proposal is aimed at eliminating the need for vacuum trucks to collect glycol at airports which do not have advanced systems in place. This system also allows for glycol to be captured so that it could be reused, as well as using a product (chitin) which could be sold to outside industries to save on purchasing cost. Dealing with changing environmental requirements is a costly venture for airports to deal with. This proposal allows for an existing infrastructure to be updated dealing with changing regulations and laws.

Experimentation Approach

Before the implementation of the experiment began, the group conducted research to determine what would be the best approach to analyze the samples produced from the experiment. Initially, research showed that a similar experiment had been conducted; however, the compound in analysis was phenol, so the group decided to use the phenol experiment as a model for the propylene glycol experiment. However, more research showed that phenol and propylene glycol were not similar, except for the fact that they are both alcohols; therefore, it was not safe to assume that propylene glycol will react the same way or even respond to the experiment. Additional research revealed that there were three possible ways to analyze the samples; since we were unsure of which approach would provide the most accurate results, we moved forward with an experimental design using all three methods, Ultraviolet-Visible Spectroscopy (UV-VIS), High Pressure Liquid Chromatography (HPLC), and Gas Chromatography-Mass Spectrometry (GC-MS).

Initial Experiment

Fifty cm^3 solutions of a mixture of water and propylene glycol were prepared in Erlenmeyer flasks, all varying in the concentration of propylene glycol contained in each solution; each sample contained about 10%, 5%, or 2.5% propylene glycol. A total of 6 samples were made; 2 for each percentage of propylene glycol. Three sets of 10 grams of chitin as well as activated carbon were then weighed out and placed in the 10%, 5%, and 2.5% solutions. Subsequently, the samples were allowed to shake for at least 24 hours, so as to make sure that the adsorption process was fully complete. After letting the samples shake for the required time, they were analyzed using the following methods outlined below.

NB: The outlined process above was repeated for each analysis (except for the analysis using Ultraviolet-Visible Spectroscopy).

Figure 3. Samples Made for Analysis

Analysis

A series of experiments were performed to analyze the binding efficiency of chitin and activated carbon with respect to Propylene Glycol. This analysis was completed using

Ultraviolet-Visible Spectroscopy (UV-VIS), High Pressure Liquid Chromatography (HPLC), and Gas Chromatography-Mass Spectrometry (GC-MS).

Analysis Using Ultraviolet-Visible Spectroscopy

Ultraviolet-Visible Spectroscopy is the absorption spectroscopy in the UV- Visible spectral region; it measures the intensity of light passing through a sample and compares it to the intensity of the base sample. A spectrophotometer consists of a light source, a holder for the sample, a diffraction grating or monochromator to separate the different wavelengths of light, and a detector. The radiation source is often a Tungsten filament (300-2500 nm), a deuterium arc lamp which is continuous over the ultraviolet region (190-400 nm), and more recently light emitting diodes (LED) and Xenon Arc Lamps for the visible wavelengths. The detector is typically a photodiode or a Charged Coupled Device (CCD). Photodiodes are used with monochromators, which filter the light so that only light of a single wavelength reaches the detector. Diffraction gratings are used with CCD's, which collects light of different wavelengths on different pixels. The samples used in UV-VIS are mostly liquids; however, the absorbance of gases and solids can also be measured.

Figure 4. UV-Vis Spectrophotometer

Preparation of Samples/Solutions and Procedure

A total of 8 solutions were made; these solutions contained (2 for each) 10%, 5%, and 2.5% propylene glycol in the waste water solution, and then one solution each for just water, and propylene glycol. Each sample was then inserted into UV-VIS; the base sample (water) and pure propylene glycol going first, while the rest of the samples followed. UV-VIS then analyzes the samples and reveals the absorption graph for each sample.

Results

Due to residues associated with activated carbon and chitin, the analysis of the binding efficiencies of both chitin and activated carbon were inconclusive using the UV-VIS analysis method.

Analysis Using High Pressure Liquid Chromatography (HPLC)

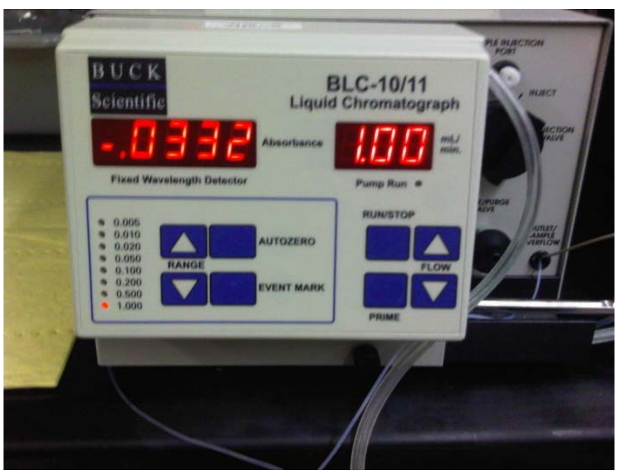

Figure 5. High Pressure Liquid Chromatograph

HPLC is a form of column chromatography used to identify, separate, and compute compounds based on their respective polarities, as well as the manner in which they react with the column's stationary phase. There are different types of stationary phases that can be used but the one that pertains to this experiment are hydrophobic saturated carbon chains. This stationary phase is a pump that moves the mobile phase and solution across the column while a detector supplies the characteristic retention time for the solution. The solution's retention time depends on the strength of its interactions with the stationary phase, the flow rate of the mobile phase, and the ratio of solvents used.

Procedure

The sample to be analyzed is introduced into the stream of mobile phase. The motion of the sample is slowed due to explicit physical or chemical interactions with the stationary phase as it travels across the column. The nature of the sample as well as the mobile phase and stationary phase all depend on how slow the sample travels. The detector then gives the time it took for the sample to make its way across the column; the sample's retention time. After each element that comprises of the sample in analysis has been separated, the amount of a specific compound/element can be found.

Results

HPLC did not entirely separate the compounds that made up the water and glycol sample; therefore, it was impossible to calculate exactly how much glycol remained in the solution.

Analysis Using Gas Chromatography-Mass Spectrometry (GC-MS)

GC-MS is a technique that combines gas/liquid chromatography and mass spectrometry to identify different substances in a sample. The gas chromatograph uses a capillary column which depends on its film thickness, length, and diameter, as well as the phase properties. Each molecule that makes up the sample has a different retention time; therefore, this allows the mass spectrometer to identify the ionized molecules separately. Furthermore, the mass spectrometer is able to complete this analysis by breaking each molecule into ionized parts, and then detecting each part using their mass to charge ratio.

Figure 6. Gas Chromatograph-Mass Spectrometer

Procedure

The sample to be analyzed is introduced to the column through an inlet; this inlet is usually an injection through a septum. The chamber is then heated to make the sample unstable, and then the carrier gas moves through the inlet to help transport the sample into the column. While another portion of the carrier gas flow is directed to cleanse any remaining sample in the inlet. The analysis of one sample takes about 8 minutes; moreover, since there were 9 samples being analyzed, it took a total time of 72 minutes to analyze every sample.

Results

GC-MS was very successful in analyzing the samples because it revealed that both chitin and activated carbon are very efficient in binding propylene glycol to their structures. Moreover, activated carbon is slightly more efficient in the binding process; the reason for this is because the chitin used in the experiments was ground to single tiny strands, which in turn did not allow enough surface area for the adsorption process, whereas, for activated carbon, the particles were more like little pebbles; in other words, there was more surface area to work with during the adsorption process. However, chitin is the most cost effective; therefore, chitin is the proposed compound to use to extract propylene glycol from the waste mixture. Furthermore, the experiments show that for every 50ml of water and propylene glycol solution, about 30g of chitin should extract the propylene glycol from the solution.

Ultimately, the group learned a great deal from implementing the previously described experiments. Also, testing innovative concepts requires a great deal of invested research and time to implement, and our proposed system is proof of that statement.

Safety Risk Assessment

As is stated in the FAA Design Competition guidelines, the FAA promotes a culture of safety in all its operations. Throughout the design process, the safety of the operators and maintenance workers was paramount as a design specification. A major resource in considering this specification was the "Introduction to Safety Management Systems for Airport Operators" in addition to the FAA Safety Management System Manual. Within these two documents, there are five different phases of what is called Safety Risk Management which allowed for quick identification of the risks and hazards that are prevalent while installing and operating our system.

Since propylene glycol is a chemical that the operators will likely come in contact with, the MSDS must be on site and readily available to the workers. In research the MSDS, it is discovered that propylene glycol is a colorless and odorless liquid that has a very low freezing point. Due to the solubility of glycol, it is important not to come into direct contact with propylene glycol or to ingest the liquid. According to the ToxFAQs provided by the Center for Disease Control, when glycol breaks down in the body, it forms chemicals that crystallize, and the crystals can collect on kidneys and affect kidney function. (Center For Disease Control, 2007) In addition, it can also form acidic chemicals that change the body's natural acid/base balance which in turn can cause serious kidney failure or even death. The CDC does state, however, that immediate diagnosis and treatment has been extremely successful in people in the past. Therefore, it is imperative that operators know to recognize the fact that they have ingested the chemical and seek immediate medical attention.

The first step in our proposed system is to collect the glycol runoff solution from the drainage system that is already in place on the apron. With this type of collection system, there are several hazards and risks associated with its operation and maintenance. For example, the runoff collected from the apron is likely to have sediment and other particulates that cannot be treated within the system itself. In addition to this, the collection of such particulates over many different events can cause a buildup of sediment and thus an increase in drag and pressure. An increase in pressure within the drainage system may cause a burst or cracked pipe leading to leaks and costly repairs of the system. To alleviate the sediment buildup, a series of filters would be implemented. With filters, however, they would need to be replaced and disposed of in an environmentally safe way.

The second step in the system will be a 100,000 gallon tank that will serve as a storage tank for storm water runoff that is not being treated. With any tanks, there are many hazards that are involved in operation and maintenance. For example, employees will have to ensure that while servicing a tank, there are safety protocols in place for proper ventilation while inside in addition to working with a team in the case of an accident. In addition to personnel safety, consideration must be given to the fact that the tank will be partially underground and will have to be routinely inspected for cracks to ensure no leaks into the environment are prevalent.

Much like the last tank, the second tank in series with the last will be a 100,000 tank that will serve as the reactor mixing tank. All safety protocols from the previous tank would be in place for the second as well. All staff must wear the proper personal protection equipment and should also be trained and certified to be operating this system.

In summary, this system will have to employ certain safety measures to ensure the personal safety of staff in addition to the protection of the environment. The combination of filters, personal protection equipment and vigilant inspections of the system will ensure a safe and efficient operation of the treatment system.

Professional Interactions

The team met with T.F Green officials to discuss the challenges faced by the airport and also help our team analyze and determine what design category we wanted to pursue. The meeting involved three airport officials: Brenda Pope, VP of Environmental Management Systems, Ann Clarke, Senior VP of Planning, Engineering and Environmental, and Ahmed Shihadeh, Manager of Engineering. Discussions took place regarding the challenges faced in airport operations, management, planning, and environmental interactions; they emphasized what challenges need to be overcome with respect to each area. Our team chose to undertake the environmental challenge T.F. Green faces with the glycol waste. Subsequently we wrote, and our proposal was accepted by T.F Green. Communication with the above mentioned contacts remained constant and positive throughout the duration of our project; information regarding techniques that other airports use to treat their waste glycol and water solution were provided to us as well as other contacts to talk to about the challenge.

Furthermore, our team conducted a survey to collect more information about how different airports around the nation treated their deicing waste. Once the survey was designed, our team contacted Melissa Sabatine, VP of Regulatory Affairs, and Leslie Riegle, Director of Regulatory Affairs, both of who work for American Association of Airport Executives (AAAE), to help distribute our survey. Communications with both AAAE employees have impacted our project positively because we now have an excellent foundation of information regarding how airports solve the problem of treating their deicing waste.

Ultimately, interactions with airport officials at T.F Green and industry experts at AAAE helped to fully understand our challenge and also direct our project in the proper research areas. During the first week in March 2010, our survey link was distributed to just under a thousand different airport executives across the nation. While we did not get the response that we anticipated, we were able to get a general consensus out of the responses that we did get. The outcome of our project shows that the interactions explained above were effective.

Projected Impacts

The overall goal of the design proposed in this document addresses innovative new methods of treating wastewater laden with deicing fluid. The implementation of a treatment system for wastewater laden with deicing fluid provides a number of environmental benefits. Primary among these is the prevention of low dissolved oxygen levels in the area of discharge. Additionally, the EPA has introduced a proposal to limit the concentration of deicing fluid that can be discharged (Environmental Protection Agency, 2009). In light of this proposal, there are roughly 200 small to medium airports that will soon be required to implement a treatment system for regulation of their discharge. Airports in the small to medium range face unique challenges in that they have neither the monetary resources nor the available landmass to implement a number of the systems in use by larger airports. As a result, a system with a low cost and short retention time is required for on-site treatment. The proposed design meets both these requirements. Additionally, chitin is both naturally occurring and renewable, since it is the substance that makes up the shells of shellfish. Depending on the location of the airport in question, it may be possible to obtain a portion of the chitin used at a discount or even no cost from shellfish shuckeries, many considering the shells a waste byproduct of operations. Furthermore, shells are frequently used in various paving applications, and the used shells may be sold to paving companies.

Financial Analysis

The two distinct cost values inherent to a treatment system are its installation cost and its operational cost. The primary components of system installation include a storage tank, a treatment tank, a mixer and motor to stir the wastewater, any additional piping, and labor. As calculated previously, an apron size of 2 acres exposed to 2 in of rain over the course of 2 days necessitates a total storage capacity of 130,000 gallons. Assuming a cost of $1 per gallon for the tanks, it will cost $130,000 for the two 65,000 gallon tanks. With an additional $20,000 for the mixer, motor, and related components, $25,000 in any required piping, and $50,000 in labor, the installation cost would be approximately $215,000.

Rainfall per 2 days	Apron size	Storage capacity	Tank Cost	Additional Costs	Installation Cost
2 in	2 acre	130,000gallons	$130,000	$95,000	$225,000

Table 2. Installation Costs

The primary components of system operation are chitin, sediment filters, electricity, and regular maintenance. Using a ratio of 30g chitin to 50mL deicing fluid, treating 1,000 gallons of deicing fluid requires 5.5 yards of chitin. At $30 a yard, or $0.033 per pound, a price obtained from speaking with Brian Dwight of South Shore Dry Dock Marine in Mansfield, MA, the cost of the chitin for treatment is $165 per day. Assuming usage 120 days in a year, this is a cost of $19,800 per year. If the used shells can be sold to a paving company for half of their original cost, however, this cost is offset to $9,900. Assuming an additional $10,000 a year for sediment filters, $10,000 for electricity, and $10,000 for regular maintenance and miscellaneous additional costs, operational cost per year would be approximately $39,900.

Deicing fluid per day	Chitin used/day	Final Chitin Cost	Total Operational Cost
1,000 gallons	5.5 yards	$9,900	$39,900

Table 3. Operational Costs

Cost/Benefit Analysis

For the purposes of comparison, the cost of the proposed design was compared to hiring a 3rd party to remove the wastewater, as well as filtration using granular activated carbon (GAC).

For 3rd Party Treatment, using an average of 4.5 inches of rainfall monthly over a two acre area, an average of 245,000 gallons of rainwater would need to be collected per month. Assuming a total of 120,000 gallons of deicing fluid is sprayed over the deicing season, there is a total of 1,600,000 gallons of wastewater per season. At a cost of $1 per 30 gallons of wastewater, based on reports from Albany International Airport (CBS6, 2009), this is a total of $53,000 per year. This results in an overall savings of $13,000 per year. At an initial cost of $215,000, it takes 17.3 years to break even.

Chitin Treatment (per year)	3rd Party Treatment (per year)	Annualized Savings	Break Even
$39,000	$53,000	$13,000	17.3 years

Table 4. Annualized Cost and Break Even Point for Chitin

For GAC Filtration, using a ratio of 25g GAC to 50mL deicing fluid, treating 1,000 gallons of deicing fluid requires 4.5 yards of GAC. At a bulk (34 lb) cost of $2020 per yard, or $2.20 per pound (WaterFiltersOnline.com, 2010), the cost of the GAC treatment is $9090 per day. Assuming usage 120 days in a year, this is a cost of $1,090,800 per year. For comparison, cost per pound of GAC from other sources was found to be $8.26 (CQConcepts, 2010) and $5.88 available in small quantities from various pet stores.

Chitin Treatment (per year)	**3rd Party Treatment (per year)**	**Annualized Savings**
$39,000	$1,090,800	$1,051,800

Table 5. Annualized Cost Comparison for GAC

Conclusion

With the deadline for the EPA's proposed effluent limitations quickly approaching, the need for a glycol treatment system for airports will become critical as airports seek possible solutions. The ability to effectively use infrastructure already in place and reduce the initial investment needed was a key component to our proposed solution. By developing the innovative chitin filtration system that was proposed, airports would have the ability to be economically prudent while still ensuring an environmentally responsible solution. With industry quickly moving towards "green" technology, the sustainability of chitin filtration could be a revolutionary approach that may well change how small to medium airports treat deicing fluids.

Appendix A: Contact Information

Faculty Advisors

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Appendix B: School Information

Roger Williams University (RWU) is an independent, coeducational, private university offering liberal arts, graduate, and professional programs. The University is accredited by the New England Association of Schools and Colleges (NEASC) and is ranked 7th in the Best Baccalaureate Colleges in the North category by *U.S. World and News Report*. Located on 140 waterfront acres in Bristol, Rhode Island, the University enrolls nearly 3,800 fulltime undergraduates, more than 260 full-time graduate students, 550 law school students and nearly 550 part-time adult learners within its seven schools and one college. RWU offers 39 undergraduate majors and seven graduate and one professional program. The University's core values include: love of learning as an intrinsic value; preparation for careers and future study; collaboration of students and faculty in research; commitment to community service; appreciation of global perspectives; and promotion of civil discourse.

Roger Williams University School of Engineering, Computing and Construction Management offers a nationally recognized ABET accredited B.S. in Engineering program and an ACCE calculus/physics based B.S. in Construction Management program. Engineering students may choose among specializations in civil (structural or environmental track), mechanical, electrical or computer engineering. All engineering students regardless of their specialization area are required to sit for the Fundamentals of Engineering exam (FE) in their senior year. Approximately 20% of all engineering students graduating from Roger Williams University immediately enroll in graduate school with the many of these students accepted directly into Ph.D. programs. Five years after graduation, 60% of the school's engineering graduates are either enrolled in a graduate program or have already completed one.

What is unique about the Engineering program is an underlying philosophy valuing a multidisciplinary approach to earning a professional degree, or education of the whole person. System-level thinking while achieving competence in specialized areas of engineering and construction is stressed. All students graduating from the Engineering program are excellent communicators both in their written as well as verbal skills. Team exercises and projects are incorporated into all classes.

The programs in the School of Engineering, Computing and Construction Management at Roger Williams University exist in an educational infrastructure that is flexible in its ability to address industry needs with regard to characteristics required in new graduates. In addition, the infrastructure is such that it encourages the introduction of new courses. It also is designed to enable faculty to engage in activities and initiatives that serve to advance their personal professional development goals while positively impacting the classroom.

Roger Williams University

Learning to Bridge the World

Appendix C: Non-University Partners Information

TF Green (RIAC)

The Rhode Island Airport Corporation was formed on December 9, 1992 as a semiautonomous subsidiary of the then Rhode Island Port Authority, now the Rhode Island Economic Development Corporation to operate and maintain the state's airport system. The powers of the corporation are vested in its seven-member board of directors, six of whom are appointed by the governor, and one member appointed by the mayor of the City of Warwick.

The Rhode Island Airport Corporation is responsible for the design, construction, operation and maintenance of the six state-owned airports; and the supervision of all civil airports, landing areas, navigation facilities, air schools and flying clubs.

In addition to T. F. Green Airport, the Rhode Island Airport Corporation is responsible for five general aviation airports throughout the state: Block Island, Newport, North Central, Quonset and Westerly.

AAAE

Founded in 1928, AAAE is the world's largest professional organization for airport executives, representing thousands of airport management personnel at public-use commercial and general aviation airports. AAAE's members represent some 850 airports and hundreds of companies and organizations that support airports. AAAE serves its membership through results-oriented representation in Washington, D.C. and delivers a wide range of industry services and professional development opportunities including training, meetings and conferences, and a highly respected accreditation program.

South Shore Dry Dock Marine

South Shore Dry Dock Marine specializes in the sale of quality pre-owned powerboats with the largest selection of sport fishing, cruising, and performance boats in the Northeast.

The inventory changes daily (over 300 boats sold per year). Owners Brian Dwight and Captain Buck Berry have many years of experience in saltwater sport fishing, boat handling and yacht maintenance.

Appendix D: Sign-Off Form

FAA Design Competition for Universities
Design Submission Form (Appendix D)

Note: This form should be included as Appendix D in the submitted PDF of the design package. The original with signatures must be sent along with the required print copy of the design.

University Roger Williams University

List other partnering universities if appropriate

Design Developed by: ☐ Individual Student ☑ Student Team

If Individual Student

Name

Permanent Mailing Address

Permanent Phone Number Email

If Student Team:

Student Team Lead Dan Shidler

Permanent Mailing Address 30 Shire Court

Cheshire, CT 06410

Permanent Phone Number (203) 687-9466 Email dshidler218@g.rwu.edu

Competition Design Challenge Addressed:

Operations and Maintenance

I certify that I served as the Faculty Advisor for the work presented in this Design submission and that the work was done by the student participant(s).

Signed [signature] *Date* 3/1/10

Name Linda Ann Riley
University/College Roger Williams University
Department(s) Engineering
Street Address One Old Ferry Rd
City Bristol State RI Zip Code 02809
Telephone 401 2543896 Fax

Appendix E: Evaluation Questions

Students

1. Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?

The FAA design competition has provided a very meaningful learning experience. It proved to be an excellent opportunity to expand our knowledge base in a number of unexpected fields, as well as a charge to apply a number of skills that we had acquired but had no real world application for. It has also served to make us aware of a significant environmental concern and the steps being taken to help remedy it.

2. What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?

Our team had a degree of difficulty in receiving continued support from our local airport. In order to remedy this, as well as to improve the overall quality of our design, we decided to take a survey of airports around the country to obtain information about their deicing processes and treatments. Additionally, we had to overcome the challenge of having limited chemistry experience on the team while trying to tackle a problem that involved a significant amount of chemistry. We overcame this challenge with the support of a number of excellent faculty members and the willingness of team members to go above and beyond exploring areas outside their chosen specialties.

3. Describe the process you or your team used for developing your hypothesis.

Our team began by meeting with T. F. Green airport and discussing areas of concern in their everyday operations. One of the greatest concerns for them was the treatment of waste water laden with propylene glycol within the very limited amount of land available to them. Once we had decided to move forward investigating effective solutions to this problem, we started solidifying our understanding of ethylene and propylene glycol and the ways in which it is currently treated, as well as the ways that it could potentially be treated. From there, it was a matter of gathering the necessary data and finding a way to quantify and compare the various methods of treatment. This involved research and experimentation, as well as a good deal of computation.

4. Was participation by industry in the project appropriate, meaningful and useful? Why or why not?

Participation by the industry was very appropriate, meaningful, and useful. Communication with the industry allowed us not only to discover the existence of a problem, but also to realize the importance and prevalence of constraints such as a small available land-area. It provided us with values relevant to quantity of wastewater collected over a given timeframe, concentration of collected glycol, and a number of other factors. It gave us an idea of how applicable our solution would be to airports around the country and what solutions were commonly employed.

5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?

We obtained a number of skills that will be highly relevant for the workforce. We have gained experience in dealing with large-scale projects involving a number of individuals in a fairly independent setting. With this comes a number of valuable skills, from time management and collaboration to research and interaction with business professionals. It also provided a number of benefits from the specific content of the project, such as the ability to practice data modeling techniques and information about environmental initiatives, which are becoming increasingly more prominent throughout businesses.

Faculty

l. Describe the value of the educational experience for your student(s) participating in this Competition submission.

The educational experience was extremely worthwhile. The competition provides an excellent platform for the senior engineering capstone design project in that the open ended nature of the challenge is exactly what is needed at that level and for that course.

2. Was the learning experience appropriate to the course level or context in which the competition was undertaken?

Yes, however the students really define how far they want to take the project with respect to stretching their intellectual boundaries. Furthermore, when working on a team project, not all of the students achieve the same level of learning. This is partly due to the division of tasks and identifying where each student's strengths lie.

3. What challenges did the students face and overcome?

The students faced many challenges on this project. The first was working with "real" clients with incredibly busy schedules. Secondly, finding the right balance with respect to team dynamic and individual responsibilities was also a challenge. Fortunately there was a very effective team manager that kept the project on track with respect to deliverables. Next, the students undertook a project for which a great deal of time was spent on ramping up their learning curve with respect to the chemistry associated with the project. Last, the final challenge was broadness of the project description from the FAA. Initially they struggled in defining their specific challenge and start the design process.

4. Would you use this Competition as an educational vehicle in the future? Why or why not?

Yes. I feel that I have learned a great deal after going through the process that I will bring to the next group of students to help them avoid some of the obstacles this year's group faced.

5. Are there changes to the Competition that you would suggest for future years?

I can understand why the FAA problem statement is proposed the way it is but the statement is almost too open ended. So much time by my student group was spent going back and forth with proposal revisions with the Rhode Island Airport Corporation to reach an approved topic to pursue. A great deal of up front time would be saved if the FAA presented a more defined design challenge that a group or majority of airports face.

Appendix F: Reference List

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Appendix G: National Survey

Deicing Treatment Methods Survey

This survey is being conducted as a component of an FAA Design Competition for Universities. A team from the senior engineering design class at Roger Williams University is seeking information from your operations group. Your input to this survey will help to support our task in addressing the Environmental Protection Agency's Proposed Effluent Limitation Guidelines Rule for Airport Deicing Operations. Please see the links at the bottom of this page for further information on the Design Competition and the EPA's proposed document on ADF's.

We thank you for taking time to fill out this short three to five minute survey. Please complete this survey by Friday, April 2, 2010 so that we may design the best and most efficient treatment system possible.

1. What method do you currently use for aircraft deicing?

- [ ] Propylene Glycol
- [ ] Ethylene Glycol
- [ ] Forced Air
- [ ] Infrared Deicing

Other (please specify)

2. What is your current method used for antiicing (pavement deicing)?

- [ ] Sodium Chloride (Rock Salt)
- [ ] Calcium Chloride
- [ ] Magnesium Chloride
- [ ] Liquid Chemical Melters
- [ ] Electric Heating Elements
- [ ] Ethanol

Other (please specify)

FAA Design Competition Website: http://faadesigncompetition.odu.edu/

EPA's Proposed ADF Limitation Guidlines: http://www.epa.gov/guide/airport/

Deicing Treatment Methods Survey - Con't

3. There are many different methods of collection including GRV's, in ground piping and plug and pump. What is your current method used for ADF (aircraft deicing fluid) collection?

4. What method do you currently employ for ADF treatment and disposal? Please elaborate if possible.

5. What type(s) of deicing fluids are used? Please select all that apply.

	Used?	Percentage Used Per Year
Type I		
Type II		
Type III		
Type IV		

Other (please specify)

6. What is the estimated quantity of deicing fluid used per year (in gallons)?

Additional Comments

7. As two of our proposed solutions, we have started experimenting with a filtration system that will use either activated carbon or chitin (the material that makes up the shell of shellfish) to remove glycol from storm water runoff.

Given your experience, do you have any advice or commentary regarding these proposed solutions?

8. Please provide any additional information that you think will benefit us in our research and development of a solution.

9. Contact Information

Name:

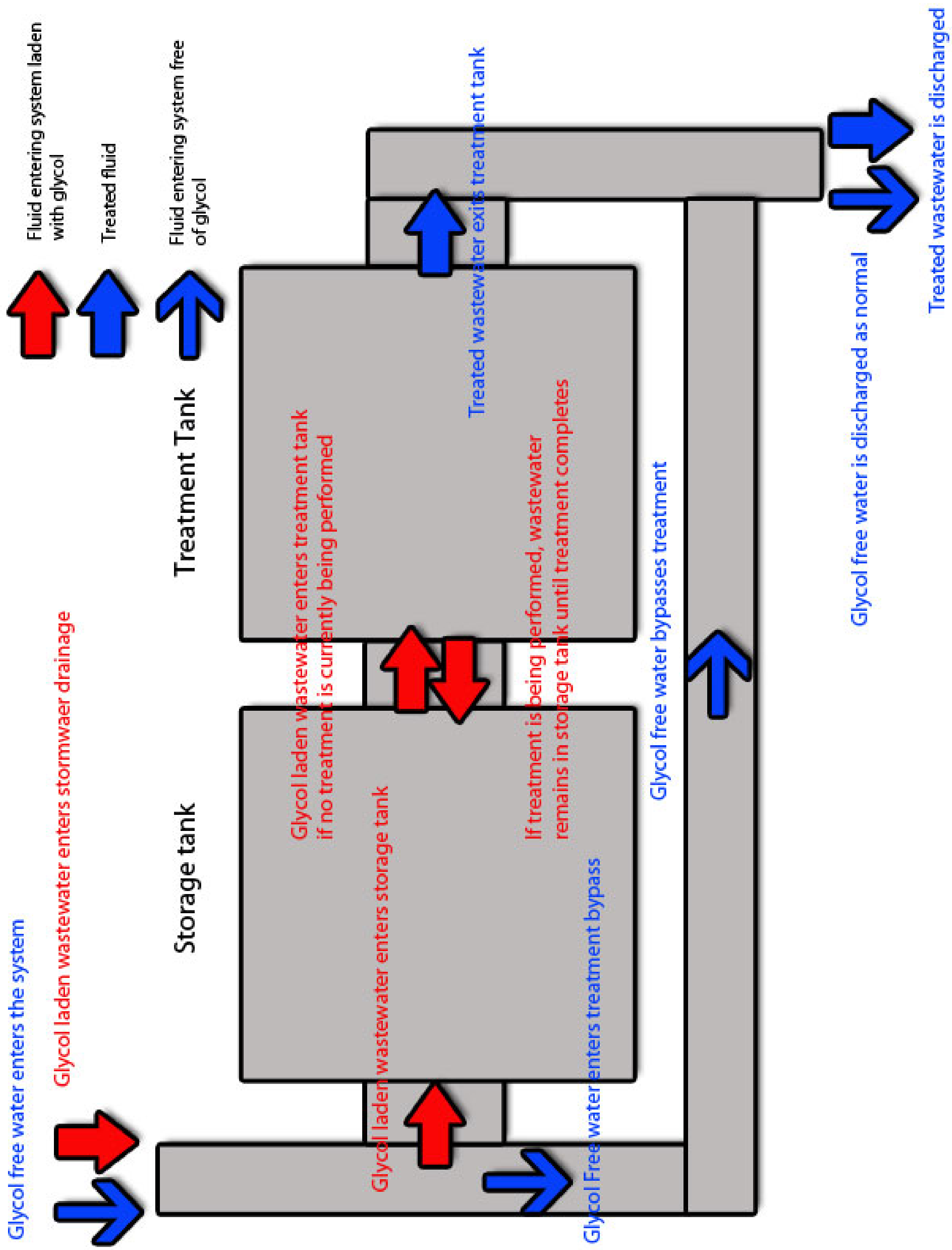
Company:

Email Address:

Phone Number:

Airport Code:

Appendix H: Full Scale Flow Diagram



Appendix I: Treatment Facility Location Map

Appendix J: Project Participants

Our group consists of five individuals, all students in the Roger Williams University School of Engineering, Computing, and Construction Management.

Dan Shidler - A senior from Cheshire, CT and will be graduating with a B.S. in Engineering. He is currently employed as a Manufacturing Engineering Intern at Sikorsky Aircraft during school recess' and his hobbies include model RC helicopters, playing the drums and is the captain of the university club men's volleyball team.

Matthew Cabral - A senior from Fall River, MA and will be graduating with a B.S. in Engineering and a specialization in Mechanical Engineering. He plans to pursue graduate studies in Nuclear Engineering next fall at North Carolina State University.

Tim Champagne - A senior from Attleboro, MA and will be graduating with a B.S. in Computer Science. He will be working after graduation as a Software Engineer for Cisco Systems and is currently involved in developing mobile applications.

David Beard - A senior from Cold Spring, NY and will be graduating with a B.S in Engineering and a specialization in Mechanical Engineering.

Onoziakpezi Agodo - A first semester Senior from Lagos, Nigeria, and is graduating with a B.S. in Engineering and a specialization in Electrical Engineering. He currently works at the university writing center as a writing tutor and is an avid basketball player.