Assessment of the Impact of a Multidisciplinary Research Program on Student Outcomes

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Abstract – The Tennessee State University (TSU) Environmental Engineering research program provides financial assistance to students at the undergraduate and graduate level. The program requires students to present the results of environmental research and projects at local, regional or national poster competitions. This paper provides a description of student involvement in the Environmental Engineering research program at TSU. An assessment of the program's impact on student outcomes based on their performance at local and regional poster competitions is also presented.

Keywords: Environmental, Multidisciplinary, research

INTRODUCTION

Environmental problems and their solutions require input from engineers, biologists, hydrogeologists, chemists, toxicologists, and political scientists. Tennessee State University (TSU) is preparing students to perform on multidisciplinary teams of experts from these diverse fields by involving students in environmental research efforts. Tennessee State University (TSU) has a dynamic and robust Environmental Engineering research program. Over the years, the research program has been enhanced through partnering with various government agencies. The program has a unique linkage to the U.S. Geological Survey (USGS) and the U.S. Army Corps of Engineers (COE). Dr. Tom Byl, an employee with the USGS, teaches graduate courses at TSU in applied microbiology and environmental chemistry and supervises the research efforts of undergraduate/graduate students. As a USGS employee Dr. Byl manages a partnership between USGS, the COE and TSU that provides TSU students with opportunities and access to resources and expertise above and beyond what is available solely through the university. Furthermore, experts in microbiology, hydrogeology, toxicology and environmental chemistry from USGS and Civil/Environmental Engineering faculty are working together on cutting edge research projects. The expertise and application capabilities of the research program have also resulted in TSU winning grants and contracts with the U.S. Army Corps of Engineers and the Water Environmental Research Foundation.

THE RESEARCH PROGRAM

TSU in partnership with the USGS has been tasked by the U.S. Army Corps of Engineers to assist in remediating 50 plus years of jet fuel spills at Ft. Campbell Army Airfield (CAAF), Kentucky. Over one million gallons of jet fuel are believed to have leaked from underground pipes at the site since the 1940's. Ft. Campbell is located on a karst terrain (limestone bedrock with conduits, caves and sinkholes), which makes ground-water remediation very difficult. Historically, remediation measures implemented at the site include pump-and-treat methods for contaminated groundwater, soil vapor extraction and excavation of contaminated soil. These measures have resulted in removal of only a small fraction of the estimated amount of fuel spilled into the environment. The pump-and-treat containment measures have had limited success due to uncertainties associated with groundwater flow in karst. In light of these challenges, the Corp specifically asked TSU and USGS to investigate and assess Monitored Natural Attenuation (MNA) as a remedial option for mitigating the impact of the spills on human health and the environment. Natural attenuation of groundwater contamination occurs at some level for all aquifers impacted with organic

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contaminants. However, the implementation of a MNA remedial alternative for groundwater requires a demonstration to regulators and the public that MNA is an effective and protective method at a given site. The issues regarding MNA being studied at TSU are: (1) whether attenuation takes place at a sufficient rate to be protective of human health and the environment and (2) if MNA is cost effective compared to other engineered remedial alternatives (e.g. “pump and treat”).

Implementation of MNA for remediation of karst groundwater at Ft. Campbell is hampered by a lack of understanding of biodegradation in karst environments. The lack of studies examining biodegradation in karst aquifers may in large part be due to the widespread perception that contaminants are rapidly flushed out of karst aquifers resulting in insufficient residence time for contaminants to biodegrade. In highly developed and well-connected conduit systems, the rate of contaminant migration is perceived to be much faster than the rate of biodegradation. This perception of contaminant transport is not entirely correct. Tracer studies for karst aquifers often indicate that these aquifers are characterized by diverse flow regimes and storage capabilities.

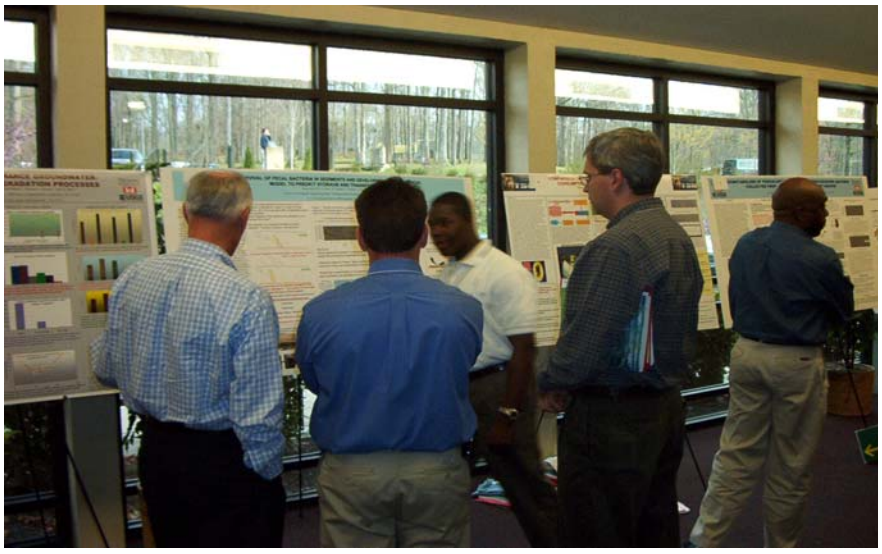
Research currently supported by the COE and underway at Tennessee State University focuses on two primary issues regarding biodegradation in karst aquifers: (1) Does significant biodegradation of contaminants occur in systems with biological activity, geochemistry and, flow characteristics found in karst aquifers? and, (2) If significant biodegradation of contaminants is demonstrated in bench-scale studies how can these results be generalized to model actual karst systems? In order to address these issues it is necessary to not only reproduce the biological and geochemical characteristics of karst groundwater in the laboratory but, also the complexities and uncertainties associated with the non-ideal fluid flow characteristics and storage capacities of a given karst system. A strong engineering design element is essential to this research effort because the MNA alternative has to be integrated with and compared to conventional engineering remedial technologies. Over the past five years, TSU Civil/Environmental research students at the graduate and undergraduate level have played a major role in advancing the Corp’s mission for Ft. Campbell.

Students Performing Experimental Work in the Environmental Lab Directed by Dr. Byl

Student research efforts have encompassed environmental engineering applications directed by TSU's Environmental Engineering faculty and microbiologists, hydrologists, and toxicologists from USGS and Ft. Campbell. Student researchers are performing experimental work in

Students Performing Field Work Directed by Dr. Byl and Other USGS Experts

TSU's environmental lab and participating in actual field studies and applications at the Ft. Campbell site. Students are required to present the results of their research at local, state and national symposiums. A partial list of research projects undertaken by students for 2000 to 2004 are shown in the table below.



Students Presenting Their Research At TAWRA Symposium.

PARTIAL LIST OF STUDENT RESEARCH PROJECTS FOR 2000 TO 2004

- Quantifying Bacteria in a Karst Aquifer with Fuel Biodegradation. *D. Agyemang*
- Biodegradation of Jet Fuel in Karst Microcosms under Anaerobic Conditions. *S. Haynes*

- BOD and COD of Fuel-Contaminated Groundwater Associated with Bioslurping. *N.Morris*
- Use of Passive-Diffusion Samplers to Measure Dissolved Oxygen and VOCs in a Karst Aquifer. *S. Namuduri*
- Developing the Rate of Benzene and Toluene Biodegradation in Karst Microcosms. *S. Roy*
- Rate of Fuel Biodegradation in Flow-through Microcosms. *S. Williams*
- Biodegradation of Fuel in a Karst Aquifer. *A. Allyson*
- The Interaction Between Calcite Precipitation and Dissolution, Carbon Dioxide and Perchloroethylene Sorption. *L. Saha*
- Evaluating a Bioluminescent Bacteria for Measuring Toxicity of Industrial Wastewaters. *R. Sarfo*
- Comparison of Lactic Acid Formulations to Enhance Biodegradation of PCE. *A. Ary*
- Enhanced Biodegradation of TCE in a Karst Aquifer Using Lactic Acid, Molasses, and Soy Milk. K. *Chakraborti*
- Identifying Microbial Degradation of PAHs Through Compound Specific Isotope Analysis of Phospholipid Fatty Acids. *A. Coleman*
- Comparison of Redox Measurements and Geo-Chemical Conditions in a Contaminated Karst Aquifer and their Influence on Biodegradation. *R. Darlington*
- Evaluation of Bioluminescent Bacteria to Serve as Sentinels of Water Quality in a Waste Treatment Plant. *M. Greene*
- Evaluating Different Oxygen-Releasing Compounds to Enhance Fuel Biodegradation by Free-Living Bacteria. *L. King*

ASSESSMENT OF STUDENT OUTCOMES

The objectives of TSU's efforts to assess the effectiveness of its environmental research program are two fold:

1. To provide faculty and other research participants with quantifiable information to facilitate continuous improvement of the program.

2. To drive student learning towards the goal of providing students with the ability to use engineering tools in engineering practice as reflected by ABET2000 criterion (k) (an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice).

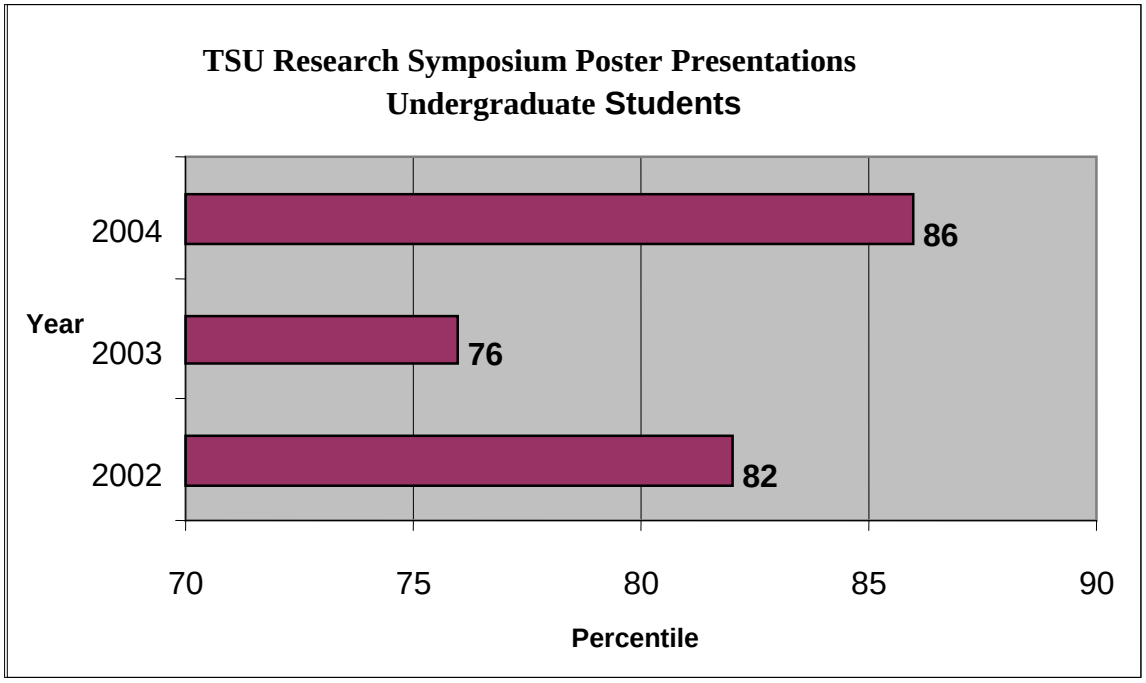
The assessment technique based on the performance of students in presenting the results of their research was planned into the program for this purpose. The results of the assessment also provide evidence of student outcomes with regard to ABET2000 criterion: (d) (an ability to function on multi-disciplinary teams) and (g) (an ability to communicate effectively).

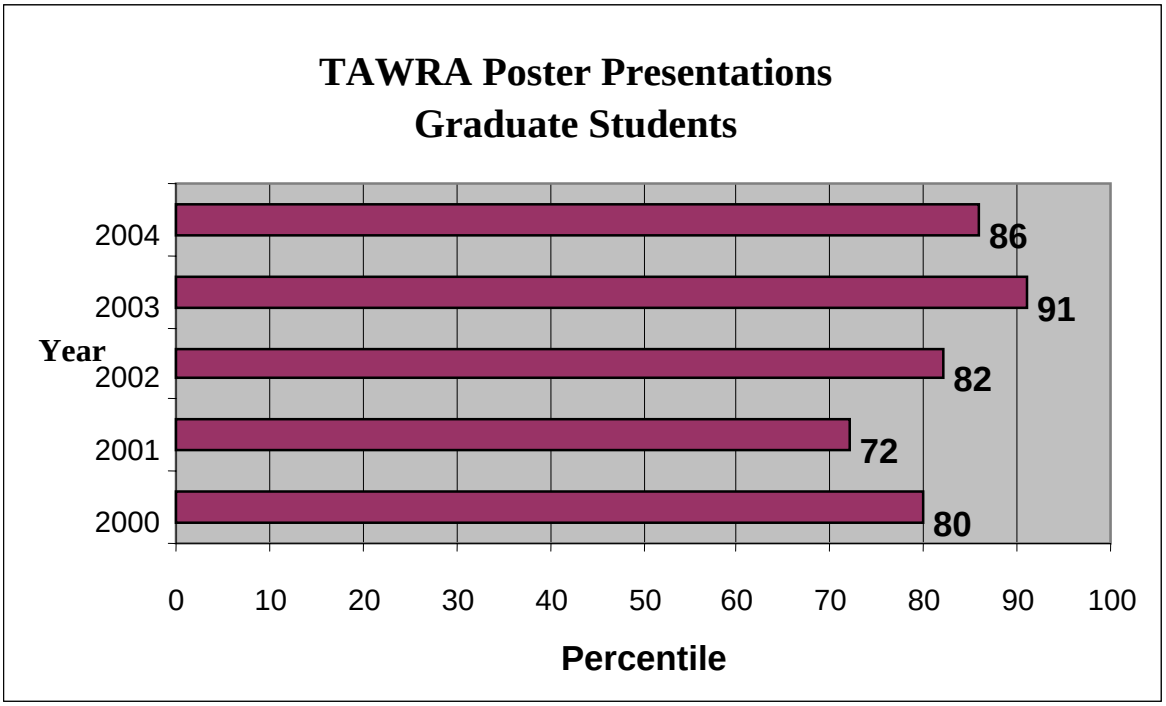
Graduate students have presented the results of their research at State and local competitions. The research presented by TSU students at the annual Tennessee American Water Resource Association (TAWRA) poster competition have won first or second place during the last five years. Undergraduate students in the environmental research program have placed first and second over the past three years in the TSU University-Wide Research Symposium poster contest. The results from the research competitions illustrate the impact of the USGS partnership and the COE support of the research program on student outcomes ,but a more quantitative assessment is needed for managing the program.

During TSU participation in these competitions the number of contestants varied from seven to twenty and the number of TSU participants varied from two to five. Clearly, TSU placing first in the 2001TAWRA contest with only six contestants has different connotations than placing first in 2003 with 20 contestants from twelve universities. The differences in the outcomes arise from the level of confidence that can be placed in the results. The uncertainty for smaller numbers of contestants arises from the fact that the underlying distribution is unknown and the number of contestants is too small for a parametric approximation to the sample space.. The difference in these outcomes can be described statistically in terms of confidence intervals for distribution quantiles. This approach is basically a non-parametric statistical inference of the contest results to an unknown distribution from which contestants are drawn each year. Even though the contestants didn't receive numerical scores the rankings of the posters can be treated as order statistics, and the probability that a certain interval contains a particular quantile of the underlying distribution is given by:

$$\Pr(Y_i \le \xi_p \le Yj) = \sum_{w=i}^{j-1} \frac{n!}{w!(n-w)!}\, p^w\, (1-p)^{n-w}$$

To create a consistent assessment tool to measure the performance of students from year to year, the upper most percentile corresponding to an 80 % confidence level was calculated for each contest result. This method of inference is applicable to any continuous distribution. These binomial type probabilities are descriptive statistics and no effort is made to describe the underlying population. The results are shown below for undergraduate and graduate students. As an example of how this approach serves as a relative indicator of student performance, note that for second place in the TAWRA contest in 2000 TSU scored 80 percentile but scored only 72 percentile in 2001 for first place. However, this is an appropriate indicator considering TSU outperformed 12 other contestants in 2000 and only five other contestants in 2001.





CONCLUSION

Feedback from TSU's industrial partners, evaluations by peers and performance in environmental engineering courses all suggest that the environmental research program is having a significant positive impact on student outcomes. The performance of students presenting their research results at competitions is especially impressive. The statistical analysis of the results of these contests presented above provides a quantitative measure of the performance of students on a university wide basis for undergraduate students and on a state wide basis for graduate students. Students have clearly benefited from their interaction and participation in the USGS/TSU environmental research program, interaction with other professionals at Ft. Campbell, and the support for research provided through the COE. The multidisciplinary and broad nature of the research projects has been viewed favorably by contest judges. This might derive, in part, because the judging bodies themselves are made up of individuals from diverse backgrounds. The research program also gives students the opportunity to take part in the actual implementation of their ideas and efforts at a major environmentally impacted site. This type of experience is rarely available to engineering students, especially undergraduate students. The open ended projects that arise from this real world application of engineering principles forces students to adopt an iterative approach to problem solving by making assumptions and adjusting their approach as the research unfolds. TSU hopes to secure more grants through its environmental research program to provide funding for a larger number of students to participate in the program. Efforts are also underway to better coordinate environmental engineering course work to the program.

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