2004 Annual Summary of Teaching, Research & Extension

Department of Biological Systems Engineering

College of Agricultural & Life Sciences
University of Wisconsin-Madison
Madison, Wisconsin

Preface

We are pleased to provide you with our 2004 Annual Summary, based on activities underway and completed in 2003. The mission of the department includes achieving excellence in teaching, research and extension. Our Biological Systems Engineering undergraduate program is accredited through 2006. The graduate program offers both Master of Science and Doctoral degrees. We have approximately 60 undergraduate and 30 graduate students. The department offers a wide range of courses with options in Machinery Systems Engineering, Food and Bioprocess Engineering, Natural Resources and Environmental Engineering, and Structural Systems Engineering.

The goal of our research program is to contribute new and valuable knowledge to the fields of food processing and instrumentation, electrical systems, machinery systems, construction, natural resources and environment, and agricultural safety and health. Research projects also serve to train graduate students and to increase the quality of undergraduate education. Our research program is financially supported by state and federal appropriations and by gifts and grants from industry, government agencies and individuals. This support is gratefully acknowledged. The gifts and grants continue to increase as a percent of budget.

Extension and outreach programs are an integral part of the department. Many of our Extension personnel are also involved in research and classroom teaching. Extension and outreach activities are directed toward providing continuing education opportunities for the citizens of Wisconsin and the nation. The mission is to extend research knowledge and to assist in assimilating it into the community.

Since this report is a summary without a lot of detail, I encourage you to contact the specific project leader (indicated by a "*" behind the person's name) or me. Publications listed in this report are available upon request.

I welcome your comments on the Annual Summary and other departmental matters. Please visit our website, bse.wisc.edu, to keep informed of our activities. Also, do not hesitate to contact me: e-mail rschuler@wisc.edu; telephone 608-262-3310; FAX 608-262-1228; or mail your comments to:

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University of Wisconsin-Madison
460 Henry Mall
Madison WI 53706 USA

Ronald T. Schuler
Professor and Chair

Table of Contents

Faculty

David R. Bohnhoff, Professor, Ph.D.
Teaching / Research: wood structures

Robin K. Connelly, Instructor
Joined the faculty in September 2003
Teaching / Research: food and bioprocess engineering

James C. Converse, Professor, Ph.D.
Teaching / Research / Extension: natural resources

Ferencz S. Denes, Associate Professor, Ph.D.
Teaching / Research: food safety

Sundaram Gunasekaran, Professor, Ph.D.
Teaching / Research: food and bioprocess engineering

Awad S. Hanna, Professor, Ph.D.
Teaching / Research: construction management

Brian J. Holmes, Professor, Ph.D.
Extension / Research / Teaching: farmstead engineering

David W. Kammel, Professor, Ph.D.
Extension / Research: farm structures

K.G. Karthikeyan, Assistant Professor, Ph.D.
Teaching / Research: natural resources and environment

Richard E. Muck, Professor, Ph.D.
USDA Agricultural Research Service: structures and environment

James O. Peterson, Professor, Ph.D.
Extension: water quality
Director, Environmental Resources Center

Mark A. Purschwitz, Associate Professor, Ph.D.
Extension / Research: agricultural safety and health
Director, UW Ctr. for Agricultural Safety and Health;
Research Scientist, National Farm Medicine Ctr. (in Marshfield, WI) as of Sept. 2003.

Douglas J. Reinemann, Professor, Ph.D.
Extension / Research / Teaching: milking equipment and facilities, rural energy, stray voltage

Roger M. Rowell, Professor, Ph.D.
USDA Forest Products Laboratory: wood chemistry, composites

Ronald T. Schuler, Professor and Chair, Ph.D.
Extension / Research / Teaching: power and machinery
Chair, UW Biological Systems Engineering

Kevin J. Shinners, Professor, Ph.D.
Teaching / Research: power and machinery

Richard J. Straub, Professor, Ph.D.
Teaching / Research: power and machinery
Director, UW Agricultural Research Stations

Anita M. Thompson, Assistant Professor, Ph.D.
Teaching / Research: natural resources and environment

Patrick W. Walsh, Professor, J.D.
Extension / Research: energy and environment, legal liability
Director, Extension Solid and Hazardous Waste Education Ctr.

Faculty with Joint or Adjunct Appointments

(Research activities and publications are not included.)

Mark R. Etzel, Professor, Ph.D. (UW Food Science)
Teaching / Research: food engineering

Robert J. Fick, Adjunct Assistant Professor, Ph.D.
Alliant Energy: rural energy

Richard W. Hartel, Professor, Ph.D. (UW Food Science)
Teaching / Research: food engineering

King-Jau (Sam) Kung, Professor, Ph.D. (UW Soil Science)
Teaching / Research: soil physics

Philip R. O'Leary, Professor, Ph.D. (UW Engineering Professional Development)
Teaching / Research: environmental quality

Aicardo Roa-Espinosa, Visiting Asst. Professor, Ph.D.
Dane County Land Conservation Dept.: urban conservation, agricultural engineering

Paul D. Thompson, Adjunct Professor, Ph.D.
Bou-Matic: milking and milk cooling

Emeritus Faculty

Glen D. Barquest
Gordon P. Barrington
Theodore J. Brevik
Edward G. Bruns
Gary D. Bubenzer
Frederick H. Buelow
Calvin O. Cramer
Benjamin F. Detroy
Marshall F. Finner
Richard G. Koegel
Leonard R. Massie

Academic Staff

Acronyms of programs/projects with which many of the academic staff are associated

AAWI – AgrAbility of Wisconsin
CASH – UW Ctr. for Agricultural Safety and Health
HFHP – Healthy Farmers, Healthy Profits Project
NAP – National AgrAbility Project

For several others, names of associated faculty follow in parentheses.

Mary F. Beck, Outreach Specialist, M.S.; NAP
Larry J. Chapman, Senior Scientist, Ph.D.; HFHP
William E. Enters, Research Specialist; Environmental Quality Lab (J.C. Converse, K.G. Karthikeyan, A.M. Thompson)
Steven D. Grunder, Associate Outreach Specialist, M.S.; NAP
Sheri L. Hicken, Associate Outreach Specialist; AAWI
Andrew Hopfensperger, Distinguished Outreach Specialist; drafting and technical illustrating
K. Gunnar Josefsson, Assistant Scientist, M.S.; HFHP
Mahmoud Kalbasi Ashtari, Research Associate, Ph.D. (K.G. Karthikeyan)
Yonghui Ma, Research Associate, Ph.D. (F.S. Denes)
Robert H. Meyer, Senior Outreach Specialist; NAP
Paul S. Miller, Research Associate, Ph.D. (K.G. Karthikeyan)
Marcia G. Miquelon, Outreach Specialist, M.S.; HFHP
Jeffrey W. Nelson, Research Specialist/Lecturer, M.S.
Astrid C. Newenhouse, Assistant Scientist, Ph.D.; HFHP
Mark E. Novak, Outreach Specialist; NAP
Derek L. Nussbaum-Wagler, M.S., Research Intern (K.G. Karthikeyan, A.M. Thompson)
Moustapha Ould Eleya, Research Associate, Ph.D. (S. Gunasekaran)
Mark E. Raabe, Research Specialist, M.S.; Midwest Rural Energy Council (D.J. Reinemann)
Scott A. Sanford, Senior Outreach Specialist; Wisconsin Focus on Energy (D.J. Reinemann)
Eun Woo Shin, Research Associate, Ph.D. (J.O. Peterson, R.M. Rowell, K.G. Karthikeyan)
Cheryl A. Skjolaas, Sr. Outreach Specialist; CASH & NAP; Interim Director; CASH
Curt C. Wilke, Associate Outreach Specialist; CASH
R.S. Williams, Supervising Research Chemist (USDA Forest Products Laboratory), Ph.D.
Ziahua (Joe) Zhou, Research Associate, Ph.D. (S. Gunasekaran)

Technical and Office Personnel

Harold M. Bohne, Senior Instrument Maker
JacqueLynn M. Cary-Pope, Financial Specialist
Yuyen Chang, Program Assistant
Hallie R. Kirschner, Program Assistant
Kelly D. Kruse, Program Assistant
Candice L. Pharo, Department Administrator
Tara A. Reeson, Financial Specialist
James F. Schwarz, Electronics Technician
Debra K. Sumwalt, Program Assistant

Graduate Students

Names of major advisor follow in parentheses

Filiz Altay (S. Gunasekaran)
Nathan Q. Altfeather (D.J. Reinemann, P.W. Walsh)
Joshua D. Bacon (K.J. Shinners)
Jeremy D. Balousek (G.D. Bubenzer)
Casey B. Behringer (K.J. Shinners)
Benjamin N. Binversie (K.J. Shinners)
Eric M. Blasing (J.C. Converse)
Perry E. Cabot (K.G. Karthikeyan)
Debora A. Costa (D.J. Reinemann)
John E. Cudoc (K.J. Shinners)
Baiyan Dong (F.S. Denes)
Milind H. Gadani (D.R. Bohnhoff)
Joseph D. Grande (K.G. Karthikeyan)
Cheng Gu (K.G. Karthikeyan)
Kerem Gungor (K.G. Karthikeyan)
Jason M. Helgren (D.J. Reinemann)
Matthew E. Herzmann (K.J. Shinners)
John S. Hingtgen (D.J. Reinemann)
Brian M. Huenink (K.J. Shinners)
Soujanya N. Jampala (S. Gunasekaran)
Sanghoon Ko (S. Gunasekaran)
Buddhi P. Lamsal (S. Gunasekaran)
Jie Li (S. Gunasekaran)
John C. Panuska (K.G. Karthikeyan)
Johna A. Roth (D.J. Reinemann)
Changhui Sun (S. Gunasekaran)
Jeffrey B. Topel (R.T. Schuler)
Anthony J. Vandermuss (A.M. Thompson)
Lan Xiao (S. Gunasekaran)
Chenxu Yu (S. Gunasekaran)

TEACHING

One part of the department's mission is undergraduate and graduate education. The department is responsible for:

- Undergraduate Major – Biological Systems Engineering
- Graduate Program:
  - Master of Science – Biological Systems Engineering
  - Doctor of Philosophy – Biological Systems Engineering
- Technical Courses
- Farm and Industry Short Courses
- College of Agricultural and Life Sciences (CALS) Student Advising

Agricultural Engineering

Currently there are about 60 undergraduate majors in Agricultural Engineering. The major consists of a core of courses taken by all students and four emphasis areas of which students choose one: machinery systems; structural engineering systems; natural resources and environment; food and bioprocess engineering. The following courses are dedicated to the Biological Systems Engineering major.

Engineering Principles for Biological Systems, 3 cr
Surveying Fundamentals, 1 cr
Field Applications in Surveying, 1 cr
Structural Design for Agricultural Facilities, 3 cr
Principles of Agricultural Machinery, 3 cr
Tractor and Power Equipment, 3 cr
Measurements and Instrumentation for Biological Systems, 3 cr
Food Engineering Operations, 4 cr
Food and Pharmaceutical Separations, 2-3 cr
Engineering Properties of Food and Biological Materials, 3 cr
Sediment and Bio-Nutrient Engineering and Management, 3 cr
Irrigation and Drainage Systems Design, 2 cr
Small Watershed Engineering, 3 cr
On-Site Waste Water Treatment and Dispersal, 2 cr
Topics in Natural Resources Engring., 1-3 cr
Career Management for Engineers, 1 cr
Fundamentals of Biological and Agricultural
Biological Systems Engineering Senior Design, 3 cr

The curriculum consists of 128 credits and is accredited by the Accrediting Board for Engineering and Technology (ABET). In July 2001 our undergraduate program was accredited for another six years, the maximum allowable.

Our curriculum currently ranks within the top five undergraduate Biological Systems Engineering programs in the U.S. During 2003, 18 students received B.S. degrees in Agricultural Engineering.

Technical Courses

The department provides a number of service courses for other majors.

Livestock Housing and Waste Management, 3 cr
Irrigation Systems – Design and Use, 1 cr
Drainage Systems, 1 cr
Surveying Fundamentals, 1 cr
Field Applications in Surveying, 1 cr
Field Machines, 3 cr
Spark Ignition and Diesel Engines, 2 cr
Tractors, 1 cr

Farm and Industry Short Course Program

The department teaches the following courses for the Farm and Industry Short Course program of the College of Agricultural and Life Sciences (CALS).

Agricultural Safety and Health, 1 cr
Agricultural Energy Management and Wiring, 2 cr
Farm Power, 2 cr
Farm Machinery, 3 cr
Livestock Housing, 3 cr
Milking Systems and Design, 1 cr

Graduate Programs

Each year there are approximately 30 graduate students pursuing a Master of Science (M.S.) or Doctor of Philosophy (Ph.D.) degree in Biological Systems Engineering. In addition, our faculty advise several graduate-level students in other departments and in the programs of Water Resources Management and Land Resources Management of the Institute for Environmental Studies. The M.S. degree requires a minimum of 18 credits of course work and 6 credits of thesis work. A Ph.D. requires a minimum of 48 credits of course work and 24 credits of thesis work for a minimum of 72 credits beyond a B.S. degree in Biological Systems Engineering. Students who have bachelor's degrees in non-engineering fields may pursue a Master's degree in Biological Systems Engineering but must complete appropriate prerequisites.

RESEARCH

Biological Engineering

Field Testing Aerobic Units and Sand Filters

J.C. Converse*

Funding: Small Scale Waste Mgmt. Project; State of Wis.
Cooperators: UW Biological Systems Engring.; UW Soil Sci.

A total of nine different aeration units were field evaluated on a total of 139 sites consisting mostly of homes but also two trailer parks and six commercial facilities with samples taken from the pump chamber. The testing period ranged from about one year to 12 years. Data were averaged per site and then the individual site means were averaged to give the overall performance for each aeration unit. Geometric mean, median, mean, standard deviation, maximum and minimum were calculated for each treatment unit. Parameters measured included BOD_5, TSS, nitrogen series, alkalinity, pH, TS, VS, COD, fecal coliform, *E. coli*, and enterococcus, along with effluent temperature and dissolved oxygen. The aeration units were divided into nine types/brands including three suspended growth ATUs, two attached growth ATUs, single pass sand filter, and recirculating sand filters subdivided into three categories.

BOD_5 means ranged from 4 to 42 mg/L, and TS means ranged from 4 to 31 mg/L. Performance consistency ranged from 49 to 99% for BOD_5 of $\leq$25 mg/L and 57 to 100% for TSS of $\leq$30 mg/L. TN means ranged from 34 to 46 mg N/L with TKN means ranging from 5 to 36 mg N/L. Nitrification in some units was incomplete. One of the attached growth units, which claims nitrogen reduction, and the RSF units did not provide the expected denitrification with the total nitrogen means from these units being similar to those of other non-denitrification units.

Fecal coliforms, *E. coli*, and enterococcus geometric means ranged from 233 to 211,000, from 624 to 217, 000, and from 102 to 5,770 col/100 mL, respectively. Performance consistency ranged from 43 to 97% for fecal coliforms and from 52 to 97% for *E. coli* of $\leq$10,000 col/100 mL.

The mean pH ranged from 7.0 to 7.7 and dissolved oxygen ranged from 1.0 to 4.6 mg/L.

Evaluation of Failing Septic Systems

J.C. Converse*

Funding: Small Scale Waste Mgmt. Project
Cooperator: UW Biological Systems Engring.

A study is underway to evaluate why some septic systems appear to be ponding or failing after a short time in operation. We will be evaluating the effluent characteristics of the septic tank effluent including bacterial robustness, along with other factors such as mass loading rates and sand quality.

Effluent Quality in Mound Toes Receiving Septic Tank Effluent or Aerobically Treated Effluent

J.C. Converse*, E.M. Blasing

Funding: Small Scale Waste Mgmt. Project; Wis. Dept. of Commerce
Cooperator: UW Biological Systems Engring.

Fifteen mound and modified mound systems with occurrences of saturation at the mound toe were sampled from the summer of 2001 to fall 2002. The mound systems received either anaerobic or aerobically treated domestic wastewater. Samples, taken from mound toe samplers and tile drains, were evaluated on the basis of mound performance using fecal coliform bacteria as the primary indicator. Soils at the fifteen sites ranged from silt loam to clay, and pretreatment devices included four septic tanks, seven aerobic treatment units (ATUs), and four packed bed filters. Effluent was distributed via pressure distribution to all systems, and approximately 50% of the soil dispersal units received effluent to only half of the infiltrative surface. Samples were taken only when the mound toe experienced saturated conditions.

Results from this study showed that mounds and modified mounds generally treat domestic wastewater during seasonal saturation to below body contact standards for fecal coliform bacteria. The mounds and modified mounds receiving septic tank effluent, ATU effluent, and packed bed filter effluent effectively reduced fecal coliform bacteria to geometric mean values of 9, 160 and 6 col/100 mL, respectively, When all pretreatments were evaluated together as a single group, the geometric mean fecal coliform count was 79 col/100 mL. BOD_5 geometric mean values of mound toe effluent were 4, 2, 5 and 2 mg/L for all pretreatment influent, septic tank influent, ATU influent, and packed bed filter influent, respectively, to the mound. Also, all categories had a total nitrogen reduction of at least 55% from the pretreatment effluent to mound toe effluent.

Field Testing of Wood Fiber-Thermoplastic Composites

R. Ibach, C. Clemons, R. Schumann, R.M. Rowell*

Funding: USDA Forest Service

Composite stakes have been prepared using several levels of fiber in polyethylene and polypropylene extruded composites. These composites have been placed in test both above ground and in ground in Madison, Wisconsin, and Gulfport, Mississippi. UV radiation effects on specimens above ground are being evaluated to determine UV degradation of both the wood and the plastic. Mold growth is also being studied on these specimens. Decay and termite attack is being evaluated on the specimens in ground.

It has been found that the higher levels of fiber loading (above 40% by weight) sorb water, and this may have a great influence on possible decay and termite attack.

Lignocellulosic Filters for Solids Removal in Recirculation Aquaculture Systems

J. Malison, R.M. Rowell*, V. Byrd, A. Krzysik
Funding: USDA Forest Service; UW-Madison

The overall goal of this project is to develop low-cost wood-based filters that can remove solids and can replace conventional biofilters for recirculation aquaculture systems (RAS). Small scale experiments were run in 2002-2003 and wood fiber filter webs have been shown to efficiently trap solids. In 2004, the project is being scaled up to remove solids from commercial operations.

Assessment of Milk Quality Management for Automated Milking Technology

D.J. Reinemann*, J.M. Helgren, P.L. Ruegg
Funding: USDA Hatch
Cooperators: UW Biological Systems Engring.; UW Dairy Sci.

Objectives

- Assess milk quality of robotic milking systems in the U.S.;
- Evaluate the economic viability of robotic milking technology;
- Identify key management factors to apply this technology successfully.

This project supported the regulatory review of robotic milking technology being conducted by the Food and Drug Administration (FDA) and the National Conference of Interstate Milk Shipments (NCIMS). A proposal to approve robotic milking for grade-A milk production was presented to the NCIMS in May of 2003 supported by the data collected in this study. The NCIMS voted to approve, and the FDA concurred in September of 2003. The PI is also the U.S. representative to the automatic milking committees of the International Dairy Federation and the International Standards Organization (ISO), which is developing the ISO standard for automatic milking installations.

Biosensor Development

D.J. Reinemann*, F.S. Denes, J.M. Helgren
Funding: H.D. Bruhn Fellowship
Cooperator: UW Biological Systems Engring.

Objectives

- Use cold plasma-aided surface modification techniques to functionalize glass surfaces for microarray applications.
- Use biomolecule attachment to verify the presence of expected surface functionalities and to demonstrate the use of these surfaces in microarray applications.

A microarray is an ordered collection of microscopic analytical elements, typically immobilized biomolecules such as DNA or proteins, on a planar substrate. Microarrays have emerged as an important tool in biological research and have been used in an enormous variety of experiments. The true power of microarrays is that a very small area can contain tens of thousands of different analytical elements, each allowing a different simultaneously-conducted experiment. Also, the small amounts of sometimes expensive reagents used in microarray experiments make certain experiments practical and others even possible. Each analytical element or spot on a microarray surface contains a different probe biomolecule. When the microarray is exposed to a solution containing a target molecule, the binding of the target to the probes can be detected, usually with a fluorescent tag.

Development of Field Tests of Milking Performance

D.J. Reinemann*, P.A. Ruegg, G.A. Mein, M.D. Rasmussen
Cooperators: UW Biological Systems Engring.; UW Dairy Sci.; UW Sch. of Veterinary Medicine; Danish Inst. of Agric. Sciences

This international team of researchers is assembling a bulletin for publication by the International Dairy Federation to give guidelines for evaluating milking performance that can be used in the field. These guidelines are based on previous research by the investigators as well as on a comprehensive review of the scientific literature on machine milking.

Milking System Clean-in-Place (CIP) Research

D.J. Reinemann*
Funding: Streams Packaging
Cooperator: UW Biological Systems Engring.

Research continues to evaluate the efficacy of new cleaning methods, chemicals, and compounds for milking machines. Efforts are focused on evaluating test methods for field application including rapid assessment using ATP bioluminescence and refining bulk tank culture methods to diagnose cleaning failures.

Development of Atmospheric Pressure Non-Equilibrium Plasma (AP-NEP) Technologies for Efficient Disinfection of Milking Machine Teat Cup Liners

F.S. Denes*, S.O. Manolache, J.M. Helgren, D.J. Reinemann
Funding: UW Ctr. for Plasma-Aided Manufacturing; UW Biological Systems Engring.

An original AP-NEP plasma reactor was designed and developed in the labs of the Center for Plasma-Aided Manufacturing (C-PAM) and Biological Systems Engineering Department to disinfect milking machine teat cup liners (*Invention Disclosure Report* submitted to Wisconsin Alumni Research Foundation). Preliminary test results indicate that this novel plasma-enhanced technology allows very efficient disinfection of teat cup liners (non-detectable bacteria levels, plasma-exposure times as low as 30 s to 2 min, high voltage power in the range of 10-50 W/liner, easy handling) without using large amounts of liquid-phase conventional disinfecting agents. The simple construction of the plasma tool, based on adapting specially designed electrodes to the liners, and the use of commercially available or custom made

(by C-PAM) high voltage power supply permits fast mass production and distribution of the device. It is expected that the implementation of plasma-enhanced milking systems will considerably reduce mastitis infections.

Plasma in *In Vivo*

F.S. Denes*, S.O. Manolache

Funding: UW Ctr. for Plasma-Aided Manufacturing; UW Biological Systems Engring.

A miniature, syringe-type plasma tool has been developed, which will permit the initiation and sustaining of the plasma state in individual tiny bubbles that are generated with controlled dimensions and formation frequency. It is suggested that the novel device could allow the disinfection of bloodstream or could produce free radicals in tumors to create tumor shrinking effects.

Generation of High Density DNA Arrays on Plasma-Functionalized Organic and Inorganic Substrate Surfaces

F.S. Denes*, S.O. Manolache, L.E. Cruz-Barba, J.M. Helgren, M.G. Lagally, B.J. Larson

Funding: UW Ctr. for Plasma-Aided Manufacturing; UW Biological Systems Engring.; UW Materials Sci. and Engring.

Conventional surface functionalization procedures of organic and inorganic polymeric substrates usually involve complex wet chemistry approaches and, in most cases, require elaborate environmentally-unfriendly, long-duration, multi-step processes. In addition, technical difficulties associated with total removal of solvents at the end of the functionalization process and with the activation of inert surfaces (e.g., polyethylene, quartz, etc.) considerably limit the use of these technologies in preparing surfaces with molecular recognition capabilities.

It was recently demonstrated in the labs of the Center for Plasma-Aided Manufacturing and the labs of the Departments of Biological Systems Engineering and Materials Science and Engineering that the low-pressure, cold-plasma approach allows the development of very efficient, dry chemistry surface functionalization mechanisms. This original method (two *Invention Disclosure Reports* submitted to the Wisconsin Alumni Research Foundation) takes advantage of plasma-generated active sites on organic and inorganic material surfaces including $SiCl_x$, $Si(OH)_x$ groups and free radical sites and their interaction with the oxirane ring (e.g., epichlorohydrin, etc.) to mediate further functionalization reactions. Successful surface functionalization reactions of polyethylene, poly(methyl methacrylate), polycarbonate, glass, silicon, and quartz substrates were accomplished using argon-, dichlorosilane- and O_2/H_2O-plasma environments followed by *in situ* reaction of active sites with epichlorohydride.

Immobilization of amine-terminated DNA on plasma modified techniques was tested using an original "sono-plot" method (patent application). It was demonstrated that high density DNA arrays can be generated and that the selective attachment of amine-terminated DNA exceeds the performances of the best commercially available arrays. The dry nature of the plasma approach and the simplicity of the entire procedure make the plasma approach very attractive. Further research is concentrating on optimizing the plasma-enhanced reaction mechanisms.

Synthesis of Nanoparticle Systems under Dense Medium Plasma Conditions (Catalytic and Magnetic Nanoparticles)

F.S. Denes*, S.O. Manolache, R.B. Timmons

Funding: UW Ctr. for Plasma-Aided Manufacturing; UW Biological Systems Engring.
Cooperator: U. of Texas at Arlington

The special properties of metallic, semiconductor or dielectric nanometer-sized structures promise numerous applications in electronic, magnetic, and optical devices and in catalytic applications due to the special physical and physical-chemical interactions developed at the atomic and atom-cluster levels. It has been suggested that every property is associated with a critical geometric scale below which the fundamental physics of the property starts to change. Nanotechnologies involve control of matter at the atomic or molecular level where quantum effects play a significant role.

Among other miniature structures, colloidal silver was considered in many investigations as an extremely efficient potential disinfectant due to its high antimicrobial activity and low toxicity to mammalian cells and tissues. It has been suggested that the smaller the silver particles, the more effective the colloid is. Bacteria exposed to colloidal silver do not develop resistance, unlike when antibiotics are used. Tetrasilver tetroxide is suggested to have biocidal properties through an electron release mechanism. The exact antimicrobial action of silver is not completely understood. Several possible mechanisms have been proposed which involve the interaction of silver with biological macromolecules such as enzymes and DNA.

Carbon-based nanoparticles (e.g., fullerenes and carbon nanotubes) and semiconductor nanoparticles have also attracted much attention because of their unique photoelectrochemical properties due to their quantum-level effects. Among semiconductors, TiO_2 is the most suitable for environmental applications. It is biologically and chemically inert. Its photocatalytic properties are favorable for oxidation of numerous hazardous chemicals, reduction of heavy metals, and photodegradation of bacteria and viruses in water.

Magnetic carbon-based, hybrid TiO_2/Ag nanoparticles and TiO_2/C/N-based nanoparticle systems were synthesized under dense medium plasma (DMP) environments. It has been shown that iron oxide containing carbon-based nanoparticle systems exhibit magnetic properties and that the photocatalytic activity of rutile has been significantly enhanced by dispersing silver nanoparticles and C/N-based structures (derived from acetonitrile-DMP reactions) into the DMP-exposed TiO_2 clusters. Applications of these hybrid nanoparticle systems can be envisaged for localized and controlled drug delivery procedures (e.g., anti-tumor drugs) and in developing efficient photocatalytic technologies to annihilate chemical and biological warfare agents.

Natural Resources and Environment

Wisconsin Pilot of Dairy Environmental Management Systems

B.J. Holmes*, G. Jackson

Funding: UW Univ.-Industry Relations; Partners for Livestock Environmental Mgmt. Systems (USDA-IFAFS); Wis. Milk Marketing Board

Cooperators: UW Biological Systems Engring.; UW Farm•A•Syst/Home•A•Syst; UW Coop. Ext. Service; private industry; Wis. Dept. of Natural Resources; Wis. Dept. of Agric., Trade, and Consumer Protection; UW Agric. Research Stations; UW Nutrient and Pest Mgmt.; USDA Natural Resource Conservation Service

Objectives

- Develop and pilot test on 30 dairy farms a computerized environmental assessment tool which will identify areas where dairy producers are doing a good job of minimizing environmental risk and those areas which need improvement.
- Work with dairy producers to develop Environmental Management Systems (EMS's).
- Present results of this project to the public and private entities which can influence decisions about using these techniques to improve dairy farm management for environmental protection.

Businesses throughout the world have adopted formal practices of business management to abide by procedures which will help them progress. Through these procedures, they identify their strengths and weaknesses and embark on a process of continuous improvement. The International Standards Organization (ISO) has established standards by which businesses can follow prescribed procedures and become certified as having followed these procedures. ISO Standard 14001 was developed to help businesses work toward environmental protection. ISO 14001 establishes the basis for standardized EMS's. Businesses other than agriculture have been voluntarily adopting this standard if they can see opportunities to improve their economic, social, and environmental status. Some adopted ISO 14001 because customers require them to use EMS's to qualify as their suppliers.

This research was initiated as part of a 9-state pilot project to determine if EMS's could be used in livestock production as a way of managing such production with reduced environmental risk and better environmental protection. Once a producer establishes his priority environmental issues, he should assess how he is doing with each of those issues. To date, 8 environmental assessment worksheets have been developed. Paper copies of these worksheets have been tested on about 30 dairy farms. A computer-based version was tested on dairy farms in early 2003. A guidebook is being written to assist in adapting EMS's for agriculture. This guidebook will be tested with dairy farmers in the spring and summer of 2004. An advisory committee has been formed to encourage acceptance of AgEMS's by the dairy industry. An EMS is nearly complete at the Agricultural Research Station in Marshfield, Wisconsin, and another has been started at the station in Arlington, Wisconsin. By developing EMS's at these research facilities, we are gaining invaluable experience prior to working on EMS's on commercial dairy farms.

Development of Polymer Application Method for Stormwater Clarification

A.M. Thompson*, A. Roa-Espinosa

Funding: CFM, Inc.; Kraus Homes; City of Sun Prairie; Polymers Plus, LLC

Cooperator: UW Biological Systems Engring.

A common management practice to control sediment is the use of stormwater detention facilities. These facilities remove sediment from stormwater runoff by reducing discharge rates, allowing time for sediment to settle out of suspension. Due to practical size limitations, these devices are usually only able to retain stormwater for a period of minutes or hours. Since silt and clay particles can require days to settle out, traditional stormwater detention facilities are not very effective at removing these particles from stormwater. The addition of sediment-flocculating polymers to accumulate and remove suspended sediment from stormwater is an attractive technology for enhancing water clarification.

The use of polymers for sediment removal in detention ponds is complicated by the temporal variability in sediment loads to the basin and the need for mixing to ensure adequate distribution of the polymer. Laboratory experiments are being conducted to determine sediment removal rates for different types of polymers and to determine optimal polymer concentrations and flow velocities for effective sediment removal. Future efforts will be directed toward developing a method for the field application of polymers.

Effectiveness of Urban Lawns to Hydrologically Disconnect Impervious Areas

A.M. Thompson*

Funding: Wis. Dept. of Natural Resources

Cooperators: UW Biological Systems Engring.; Wis. Dept. of Natural Resources; U.S. Geological Survey; UW Civil and Environmental Engring.

Accurate stormwater runoff prediction depends on the amount of impervious surface area within a watershed and the level of connectedness of that impervious area. Although the degree of imperviousness is relatively simple to quantify, the level of connectedness is not. The issue is further complicated by the lack of understanding of the hydrologic response of urban semi-pervious areas. The goal of this project is to quantify the rainfall-runoff response of urban residential lawns and determine their ability to hydrologically disconnect impervious surfaces. Two seasons of field experiments on residential lawns will be conducted. The first season will focus on simulated rainfall events and the second season will focus on natural rainfall. We are modifying a continuous simulation groundwater recharge model, RECARGA, for use in predicting the rainfall-runoff response of urban lawns. Field data will be used for model validation.

Impact of Impervious Surfaces on Stormwater Runoff Temperature

A.M. Thompson*

Funding: USDA Hatch

Cooperators: UW Biological Systems Engring.; Dane County Land Conservation Dept.

Impervious surfaces in urban areas are a source of thermal pollution in cold climates and threaten the health of cold-water ecosystems. Impervious surfaces absorb energy from the sun and warm up. As water runs over these warm areas, the runoff absorbs some of that heat. The higher temperature of the runoff raises the temperature of the receiving waters. Increases in water temperature above ambient levels can result in direct impacts or changes in water quality that lead to biological impacts.

Rock cribs are a current management practice to lower runoff temperature before the runoff enters thermally sensitive water bodies. A laboratory study is being conducted to quantify the effectiveness of cribs in reducing runoff temperature. Results from the laboratory experiments will be used for model validation and to develop design standards for the use of rock cribs as temperature reduction devices. Future work will include a field experiment, conducted at the UW West Madison Agricultural Research Station, to study increases in pavement temperature and the subsequent transfer of the heat to stormwater runoff.

Infiltration on Compacted Urban Soils

A.M. Thompson*, N.J. Balster

Cooperators: UW Biological Systems Engring.; UW Soil Sci.

The construction process disturbs and compacts urban soils, and soil structure is altered. Understanding infiltration characteristics of urban soils and methods to restore soil structure are critical for predicting and managing stormwater. A study is being conducted at the West Madison Agricultural Research Station. The study involves extracting soil cores from undeveloped and developed areas and is designed to measure the degree to which native grasses can restore pre-development bulk density and water infiltration rates relative to conventional sod lawn.

Restoration of a Drained Lake Basin at Franbrook Farm

N.J. Balster, J.A. Harrington, A.M. Thompson*

Funding: UW Sch. of Natural Resources

Cooperators: UW Biological Systems Engring.; UW Soil Sci.; UW Landscape Architecture

Following small dam removal, the resulting landscape is often restored to plantings of low diversity consisting of species capable of rapid establishment and erosion control. Prior to removal, the reservoir behind a dam often serves as an area of sediment accumulation and deposition. After dam removal, a soil is exposed that is often nutrient-rich, high in organics, and compacted. The physical and chemical characteristics of this newly exposed sediment may have significant control over species composition and establishment. Coupled with the changes in the hydrologic response, the ecological succession of these basins becomes difficult to predict.

The Wisconsin Department of Natural Resources drained a 3-hectare, 40-year-old pond in southern Wisconsin in January, 2003. This basin provides the setting for this research on re-establishing native prairie vegetation. The study is designed to gain quantitative understanding of how the natives interact with gradients in soil and hydrologic characteristics across the basin, as well as differences in microtopography. We are investigating relationships between temporal changes in restored prairie vegetation, planted at four different seeding rates, and changes in soil and hydrologic processes relative to invasive species within the drained basin.

To date, experimental plots have been delineated and preliminary soils and infiltration data have been collected throughout the basin. From the preliminary soils data, we have determined water release curves, bulk density, total porosity, particle size distributions, and volumetric water content spatially throughout the basin. Experimental plots will be seeded in spring, 2004.

Removal of Phosphorus from Farm Runoff

R.M. Rowell*, S.H. Min, D. Eustice, J. Han

Funding: USDA Forest Service, State of New York

Cooperator: State of New York

Filters made of juniper fiber that were used to remove heavy metal ions in the Wayne National Forest are used to remove phosphorus from one section of the water supply for New York City. The phosphorus comes from runoff from two farm milking operations located along one of the major streams used for the city. More than 80% of the phosphorus can be removed by using the wood fiber filters. This project was completed in 2003 and a final report has been sent to the State of New York.

Use of Cold Plasma to Functionalize Fibers for Filtration Research

F.S. Denes*, R.M. Rowell*, J.O. Peterson*, M. Tshabalala, D. Eustice

Funding: USDA Forest Service, Forest Products Lab; UW-Madison

A new cold plasma laboratory is being built at the Forest Products Lab to modify the surface of wood fibers to improve their ability to sorb contaminants from water. A small rotating reactor is being installed that will functionalize low-cost-wood fiber which will then be made into fiber webs using the Rando web-forming technology.

The chemically modified fiber mats will be used to remove both cations and anions as well as other toxic organics from contaminated water. We will work with the University of Wisconsin on water runoff on campus.

Removal of Heavy Metals from Acid Mine Drainage in a National Forest

R.M. Rowell*, J. Han, D. Eustice

Funding: USDA Forest Service; Wayne National Forest
Cooperator: Wayne National Forest

The Wayne National Forest contains many old mine sites that are contaminating the area's watersheds. This contamination results from low pH and the presence of soluble heavy metal ions (Mn, Zn, Fe and Al). The Forest Products Laboratory of the USDA Forest Service has installed a filtering system to neutralize the acid and remove targeted heavy metals from the Addis mine drainage discharge using lignocellulosic fiber-based filters.

An analysis of the discharge shows that the total concentration of heavy metals is about 800 ppm with high concentrations of Fe (47 ppm), Mg (75 ppm), and Al (16 ppm). The pH of the discharge is between 2.0 and 3.1 (average 2.8) with a flow rate between 1 and 8.5 gal/min (average 2 gal/min).

The filters were installed in Spring 2002. The first set of data shows that the fiber-based filters, along with a change in pH to 5, removes more than 80% of the Fe and Al. A second data set was obtained from continuing research during 2003. Similar results were obtained from this recent set of data. The filter system may be moved closer to the mine as the small output from the mine is diluted by rain water before it gets to the filter system.

Development of a Natural Fiber System to Clean Runoff Waters

J.O. Peterson*, E.W. Shin, R.M. Rowell

Funding: USDA Forest Service, Forest Products Lab
Cooperators: UW Biological Systems Engring.; USDA Forest Service

Fiber from pinyon juniper (*Juniperus monosperma*), a small-diameter and underutilized lignocellulose material, was processed to form a filter mat which was used to remove heavy metals from acidic mine drainage. The metal-laden filters were known to remove phosphorus (P) from runoff waters. Lab-scale batch tests of sorption capacity showed uptake of 1.85 mg/g (Langmuir isotherm model). Kinetics tests fitted to a pseudo-second order model resulted in a k value of 8.09×10^{-2} g/mg/min at 10 mg/L P concentration. The high sorption capacity and rapid kinetics should prove useful for removing P from runoff in agricultural watersheds. Field testing is planned for a site in New York City's water supply watershed.

Phosphorus Dynamics in Soils Receiving Chemically Treated Manure

K.G. Karthikeyan*, M. Kalbasi

Funding: Wis. Fertilizer Research Council

This study attempts to bridge the gap between our knowledge of chemical treatment systems for dairy manure intended to remove phosphorus (P) and solids and the ultimate fate of P when the treated manure is land applied. Our results, in conjunction with those from chemical treatment studies, will help select optimum formulations of chemicals (coagulants and flocculants) that can maximize concentration of solids/nutrients in dairy manure as well as provide the greatest protection against adverse water quality effects. Our findings are critical for designing any chemical treatment and land application systems, which will provide increased options to manage dairy manure.

An incubation study (1 d to 1 yr) was conducted with 3 soils (I, II, III with 12, 66, 94 mg/kg Bray-1 P), 4 manure treatments (1 untreated; 3 chemically treated [alum – Al; $FeCl_3$ – Fe; lime – Ca]), at 2 rates (12.5, 25 mg P/kg), and a control (no manure). Sub-samples were analyzed for Bray-1 P and water-extractable P (WEP) after 7 incubation time periods (1 d; 1 and 2 wks; 1, 3 and 6 mos; 1 yr). P distribution among different fractions (soluble and exchangeable; Al-, Fe- and Ca-bound; organic-P and residual) was also determined after 1 d and 1 yr. WEP increased when soils received untreated or Ca-treated manure in proportion to P application rate. WEP, however, decreased compared to control for soils II and III or slightly increased for soil I with addition of Al- or Fe-treated manure. WEP decreased sharply between 1 d and 1 to 2 wks and then remained relatively constant or increased slightly up to 1 yr depending on treatment and soil type. Bray-1 P increased for all treatment types and soils in the following order: Ca-treated > Al-treated $\geq$ untreated > Fe-treated > control. Bray-1 P decreased within each treatment between 1 d and 1 to 2 wks and then increased gradually for up to 3 months (soils II and III). Application of Al- or Fe-treated manure decreased P solubility with the effect more pronounced in soils with high background P. Application of Ca-treated manure, however, increased both WEP and Bray-1 P. Several years of P input through manure and fertilizer contributed mainly to Al-P and, to a lesser degree, to other fractions. Only soluble and exchangeable P (all soils) and Al-P (soil I) exhibited treatment-type effects after receiving chemically treated manure.

A Systems Approach to Improving Phosphorus Management on Dairy Farms

K.G. Karthikeyan*, J.D. Grande, M. Kalbasi, J.M. Powell

Funding: USDA-Natl. Research Initiative
Cooperators: UW Biological Systems Engring.; US Dairy Forage Research Ctr.; UW Soil Sci.; UW Agric. Research Stations

Interest in using corn silage is growing due to changes in animal farm dynamics and favorable economics compared to alfalfa. The extent of residue cover influences runoff production and soil losses, and hence these changes will affect the off-site migration of sediment-bound nutrients. Since high-cut silage will increase residue cover, this method could conceivably minimize water quality degradation that would otherwise result from harvesting corn for silage. We examined the effect of different corn harvesting schemes and manure application timing on sediment and P losses from no-till fields. Treatments included conventional corn grain (CG) and silage (CS) and non-conventional high-cut (24-26 inches) silage (CS-H). Each treatment received one of three manure treatments: no manure, spring, or fall application.

Simulated rainfall experiments (7.5 cm/h for 1 h) were performed in spring and fall, runoff from 2×1.5 m plots was collected, and a sub-sample was analyzed for total sediments, dissolved reactive P (DRP), total P (TP), particle size distribution, and P mass in different size classes. Compared to CS, CS-H was effective in reducing sediment and P losses; the reductions were greatest in fall runoff and were enhanced by adding manure. Although sediment, DRP, and TP concentrations were higher under manure application, the secondary effect of enhanced infiltration resulted in lower values on a load basis. DRP concentration was sensitive to manure application timing while TP concentration was not. Compared to no manure treatment, DRP levels for all treatments were five times greater following spring application, while TP concentrations were highest under no manure. Spring application led to a lower percentage of sediments in the size range >2 μm following spring rainfall. Few differences among treatments were observed in the particle size distribution for fall runoff. Compared to coarser fractions, sediments <10 μm were enriched in TP by 31-105%. CS-H may lead to less runoff and lower sediment export. However, it can potentially enrich runoff with P due to selective delivery of fine-sized particles with higher P levels.

Quantifying Phosphorus Losses from Agricultural Fields

K.G. Karthikeyan*, P.S. Miller, J.M. Norman

Funding: USDA Natl. Integrated Water Quality Program, Integrated Research, Education and Extension Applications
Cooperators: UW Biological Systems Engring.; UW Soil Sci.; Wis. Discovery Farms Program

The goal of this research is to use a process-level model to quantify phosphorus (P) losses from farm fields under different management options and then to extend the use of this model to recommend practices that would minimize water quality degradation. The objective is to add sediment loss and P-chemistry components to an existing Precision Agricultural-Landscape Modeling System (PALMS), evaluate key runoff parameters with measurements on several field plots, and test the model over the entire sub-watershed using U.S. Geological Survey (USGS) stream monitoring data. The selected watershed is known to be subject to large P losses from USGS stream monitoring (0.5 mg P/L) and is a Wisconsin Discovery Farm, one of 30 such farms chosen from a pool of volunteer farmers to represent standard farming practices and to serve as a focus for research that will maintain profitability while improving environmental health. Therefore, this study will benefit directly from the Discovery Farm infrastructure, and results will be directly transferable to other Discovery Farms.

4D-P is a spatially and temporally distributed agricultural P-cycling model being built as part of PALMS. PALMS is a complex environmental simulation model integrating diffusive wave runoff routing with ponding capabilities and a biosphere simulator. The General Erosion Modeling Subroutine (GEMS), a new module which integrates the algorithms from WEPP for spatially distributed applications, has also been included. 4D-P is being built into this system to model P cycling within an agricultural field and is an extension of the P-modeling systems developed and incorporated in EPIC and SWAT. Five sub-modules comprise 4D-P: INITP, a 3-dimensional P soil initializing sub-module; PSSL, a P-cycling single soil layer sub-module; PMOVE, a chemical transport sub-module; PTILL, a tillage and fertilizer sub-module; and PSUM, a chemical transport aggregator that tracks and accounts for P redistribution across the landscape. Each module will track P cycling at various time steps from seconds for PMOVE to singular event occurrences such as tillage operations in PTILL. Results will be contrasted with field data including total dissolved P and total P from three fields established under different crop harvesting and manure management systems at the UW Agricultural Research Station in Arlington, WI.

Inorganic Phosphorus Forms and Extractability in Anaerobically Digested Dairy Manure

K.G. Karthikeyan*, K. Gungor, M. Kalbasi

Funding: USDA CSREES Hatch

Anaerobic treatment technology reduces waste disposal costs, conserves energy, reduces pathogens, and eliminates off-gas air pollution. Research on anaerobic treatment of manure has focused on the influence of different process configurations and operational variables. The effect of anaerobic treatment on phosphorus (P) forms and extractability must also be investigated as manure nutrient management is a fundamental issue in agricultural non-point source pollution control. This study combines macroscopic experiments and chemical equilibrium modeling to evaluate changes in P extractability and forms after anaerobic digestion of dairy manure. Influent (substrate) and effluent (inoculum) samples were collected from a Wisconsin dairy farm that has a full-scale anaerobic digester in operation. Standard biochemical methane potential (BMP) test was run using these samples under mesophilic conditions (35°C). Since the major cations (Ca and Mg) controlling P solubility in manure also form strong complexes with volatile fatty acids, P chemistry can be affected by the anaerobic organic degradation process. We used two significantly different inoculum-to-substrate ratios (2 and 0.3 g VS inoculum/g VS substrate) to understand the effect of organic solids destruction on P dynamics in anaerobically treated manure. Serial (increasing extractant-to-sample ratios between 3 and 127) and sequential extraction (6 extractions with an initial extractant-to-sample ratio of 3) protocols were applied on the manure mixture obtained before and after anaerobic digestion. DI water and 0.01 M $MgCl_2$ were used as extractants in serial extraction while only DI water was used for sequential extraction. Dissolved metal concentrations, dissolved reactive P, Ca^{++}, pH, and electrical conductivity were measured after the extractions. Chemical equilibrium modeling using Mineql+ revealed that struvite is the likely P solid phase controlling its solubility until the third sequential extraction during and after the BMP test. Suppression of P solubility at low extractant manure ratio in the presence of 0.01 M $MgCl_2$ supports this observation. Water extractable P slightly increased at the end of BMP test for both high and low inoculum-to-substrate ratios. Total biogas production was higher in low inoculum-to-substrate set; yet net biogas production values were not significantly different.

Forest By-Products as Filtering Aids for Nutrients

K.G. Karthikeyan*, M.A. Tshabalala, M. Kalbasi, D. Wang

Funding: USDA Forest Service, Forest Products Lab
Cooperators: UW Biological Systems Engring.; USDA Forest Service

We investigated the suitability of using modified (cationized) bark or wood fibers from southern yellow pine to function as phosphorus (P) sorbents. Adsorption of orthophosphate anions in aqueous solution by cationized milled solid wood residues was characterized as a function of sorbate-to-sorbent ratio (0.001-1.26 mmoles P/g substrate), pH (3-9), ionic strength I (no I control; 0.001 and 0.01 M NaCl), reaction time (4 min-24 h), and the presence of other competing anions (0.08-50 mM SO_4^{2-}; 0.08-250 mM NO_3^-). Sorption isotherms revealed the presence of two kinds of adsorption sites corresponding to high and low binding affinities for orthophosphate anions. Consequently, a 2-site Langmuir equation was needed to adequately describe the data over a range of solution conditions. In addition to higher sorption capacity, cationized bark possessed higher binding energy for orthophosphate anions compared to cationized wood. The sorption capacity and binding energy for bark were 0.47 mmole P/g and 295.7 L/mmole, respectively. Corresponding values for wood were 0.27 mmole/g and 61.4 L/mmole. Both the sorption capacity and binding energy decreased with increasing I due to competition from Cl^- ions for the available anion exchange sites. Surface charge characteristics of cationized bark (pH_{zpc} = 7.9) acted in concert with orthophosphate speciation to create a pH-dependent sorption behavior. Orthophosphate uptake was quite rapid and attained equilibrium levels after 3 h. Both SO_4^{2-} and NO_3^- influenced percent removal but required high relative competing anion to $H_2PO_4^-$ molar ratios (2.5-3 for SO_4^{2-} and 25 for NO_3^-) to cause appreciable reduction. These results support our hypothesis that adsorption of orthophosphate anions on cationized bark involves ion exchange and other specific Lewis acid-base interactions.

Nitrogen and Solution Dynamics in Soils Receiving Chemically Treated Manure

K.G. Karthikeyan*, M. Kalbasi

Funding: Wis. Fertilizer Research Council

Chemical treatment of animal manure with Al, Fe, and Ca salts appears capable of concentrating P into a smaller volume, thereby providing more manure management options. However, very little information is available on the fate of nutrients in soils receiving chemically treated manure. An incubation study was conducted to determine the effect of chemically treated manure addition (three treatments: alum – Al; $FeCl_3$ – Fe; lime – Ca) on short- and long-term dynamics of nitrate (NO_3^-) and ammonium (NH_4^+) in soils. Two application rates were used in addition to a control sample (no manure). Sub-samples were analyzed for pH, electrical conductivity (EC), water-extractable NO_3^-, NO_2^-, and K^+-extractable NH_4^+ after 1 d, 1 and 2 wks, 1, 3 and 6 mos., and 1 yr. Soil pH increased significantly for the application of Ca-treated manure after all incubation periods and was sensitive to the application rate. However, it decreased (sharply between 1 d and 1 or 2 wks) or remained unchanged (compared to control) for the other treatments. Nitrate release was controlled by the treatment type (untreated > Al-treated > Ca-treated > Fe-treated > control) and increased sharply between 1 d and 1 or 2 wks and then slowly at longer incubation periods. Although more NO_3^- was extracted at the higher application rate, both rates had similar percent of the total applied N released as NO_3^- ($PWENO_3$). The trend in EC followed that of water-extractable NO_3^-, resulting in an excellent correlation (r^2 = 0.96) between the two variables. In contrast to NO_3^-, K^+-exchangeable NH_4^+ exhibited a sharp decrease between 1 d and 1 wk of incubation and then remained relatively constant for up to 1 yr. The decrease in exchangeable NH_4^+ during the first week followed this order: untreated > Al-treated ≥ Fe-treated > Ca-treated > control. Applying chemically treated manure appears capable of decreasing the extent of initial rapid nitrification. Besides short-term effects, adding $FeCl_3$ is effective in lowering $PWENO_3$ even after 1 yr of incubation.

Measuring and Modeling the Source, Transport and Bioavailability of Phosphorus in Agricultural Watersheds

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Funding: US Environmental Protection Agency (STAR Program)-Nutrient Sci. for Improved Watershed Mgmt. Program
Cooperators: UW Biological Systems Engring.; UW Civil and Environmental Engring.; UW Forest Ecology and Mgmt.; UW Rural Sociology; UW-Platteville; Wis. Dept. of Natural Resources

The focus of this project is on scale-dependent processes that link agricultural phosphorus (P) sources to watershed export of bio-available P (BAP). Specific objectives are to quantify the effects of manure management on runoff BAP and to determine the relation of BAP losses to the scale of animal operations. First, this research addresses the need to validate plot-scale research studies at coarser scales. This issue is of growing importance in understanding the effect that the watershed flow system has on P delivery from agricultural fields. Second, it illustrates how field-scale studies can be conducted without greatly compromising the detail provided by research at finer scales. A research design is being used involving sheet-flow samplers that are capable of capturing runoff from fields comparable in size to fields farmers actually manage. Finally, we will use manure management as a research variable at the scale that farmers manage animal manures.

Factors affecting P export from agricultural fields are usually grouped according to their potential to affect its off-site migration. Management is considered a sub-factor of transport processes despite the fact that a single management factor, such as manure placement, will often have diametric effects on source and transport factors. Because management behavior involves a critical "human dimension," a compelling case can be made to isolate it as a separate, unique category of factors that influences off-site P losses. The timing of manure application is crucial due

to the hyper-vulnerability of surface-applied manure to rapidly supply large quantities of P to the environment in the event of a storm shortly after application. The current body of research on the timing of manure application as it affects surface P losses was conducted at scales much smaller than field sizes farmers actually manage. This study will provide results from field-scale studies in which manure was applied to cropland directly prior to the onset of natural rainfall. The purpose of this research is to validate at larger scales the results of plot-scale research on P delivery as it is influenced by the interval between manure application and rainfall. We will present temporal trends in dissolved reactive P, total P, P associated with five particle size fractions, and aggregate stability for runoff samples collected from fields cropped in corn and alfalfa. The results will help in making sound management decisions for animal manure applications.

Sorption of Tetracycline and Fluoroquinolone Antibiotics to Inorganic Mineral Surfaces

K.G. Karthikeyan*, C. Gu, J. Pedersen

Funding: Wis. Groundwater Coordinating Council; UW Water Resources Inst.; Wis. Dept. of Natural Resources; Wis. Dept. of Agric., Trade, and Consumer Protection

Cooperators: UW Biological Systems Engring.; UW Soil Sci.

Antibiotics are used extensively in human therapy, veterinary medicine, and as animal husbandry growth promoters. Reports of antibiotics being detected in surface and ground water have heightened concern about the presence of these emerging contaminants. In our recent statewide survey, we detected eight compounds in five classes with the following order in frequency of detection: sulfonamides > tetracyclines > fluoroquinolones > trimethoprim > macrolides. Our ability to predict the fate and mobility of antibiotics is hampered by a lack of information on fundamental processes governing their environmental reactivity. The sorption process is particularly important as it influences the mobility and transport of antibiotics in surface and sub-surface environments and affects their propensity to undergo transformation reactions. Experiments are underway to quantify the sorption of 7-^{3}H-tetracycline and 2-^{14}C-ciprofloxacin to hydrous oxides of Al and Fe. Loss of antibiotics from solution is being measured using liquid scintillation counting (LSC) and compound-specific HPLC analysis to accurately quantify sorption and also to monitor transformation of the parent compound. Preliminary results indicate that tetracycline sorption to Al hydroxide follows a slight pH-dependent trend, whereas strong pH dependence is observed for ciprofloxacin. A slight increase in tetracycline removal (LSC-determined) occurred between pH 4.2 to 5.3 (36 to 40%) above which it continued to decrease up to pH 9.5 (22%). Sorption of ciprofloxacin increased sharply between pH 4.1 to 5.5 (32 to 66%) and then decreased with increasing pH (38.5% at pH 9). Also, there is a significant difference (1.9 to 2.7 times) between LSC and HPLC measurements for tetracycline, attributable to transformation and/or complexation with dissolved metal ions, while ciprofloxacin appears to be more stable in solution. Spectroscopic analysis will be employed to elucidate the underlying mechanisms of interaction. Our research results will increase understanding of the environmental fate and reactivity of these emerging contaminants.

Structures / Construction

In Situ Hydration of Dry Concrete Mix

D.R. Bohnhoff*, D.W. Kammel, Z.D. Hartjes, N.P. Ryan

Funding: UW Biological Systems Engring.; Wis. Frame Builders Assn.

Through the years, many post-frame builders have placed dry concrete mixes into post holes and then backfilled the holes without adding water to the dry concrete mix (i.e., without hydrating). When placed in this fashion, it is assumed that water in the soil permeates into the mix, hydrating and growing cement particles to form a consolidated mass of concrete. Hydration of a dry concrete mix after the mix has been covered with soil is herein referred to as "*in situ* hydration".

In situ hydration was first used to form entire post footings. Such reliance on *in situ* hydration was largely restricted to smaller agricultural and other non-commercial buildings. As average post-frame building size increased and engineering became more advanced, forming post footings entirely from non-hydrated concrete mix was phased out. Today *in situ* hydration essentially is only used to form above-footing collars as part of a post uplift resistance system and under precast concrete footing pads to increase the size of the footing. When used under a precast concrete pad, concrete hydrated *in situ* need only have compressive strength equal to the pressure at the bottom of the precast footing. Generally this is a relatively low pressure and one that a confined concrete dry mix may have prior to being hydrated. It is important to note that whereas infiltration of water into a soil mass reduces the bearing capacity of the soil mass, such infiltration will increase the bearing capacity of a dry concrete mix.

Relying on *in situ* hydration has several advantages.

- Concrete gets used in small portions as needed, whereas truck deliveries of concrete would require simultaneous placement of all footings/collars.
- Water is not required on-site.
- Cold weather is a non-factor.
- The time associated with clean concrete mixing and placement is eliminated.
- Planning is easier; the construction schedule is not dictated by concrete delivery.

Although *in situ* hydration has been practiced for well over a quarter of a century in Wisconsin, it is only allowed in construction of agricultural and other code-exempt structures. Before Wisconsin code officials will allow use of concrete hydrated *in situ* in code buildings, its properties must be quantified, and guidelines/procedures for placement of concrete dry mixes must be established.

In 2001, as a first step in investigating the degree to which a dry concrete mix hydrates *in situ*, UW-Madison researchers conducted a field study of compression tests on cores removed from concrete collars hydrated *in situ* for less than a month. Since the average strength of these cores exceeded a respectable 2000 psi, a decision was made to conduct a more controlled laboratory study.

In the summer of 2002, six 300-gallon livestock tanks were filled with sand meeting the requirements of ASTM C33. Buried

in each tank were nine cylinders of dry concrete mix. Each cylinder was approximately 12 inches in diameter and 5.5 to 6 inches thick. The cylinders in each tank were buried at three different depths. Tanks were paired off and each pair was subjected to a different water treatment. Moisture was monitored at four depths in each tank using Echo moisture probes. Three cylinders were removed from each tank after being in place one month. Three more were removed after three months, and the last three were removed after being in place six months. The cylinders were cored as soon as they were removed, and the cores were immediately capped and tested.

Data collected during 2002 were analyzed in early 2003 and the following was concluded.

- *In situ* hydration of a dry concrete mix can produce concrete with a compressive strength comparable to a normally hydrated concrete mix.
- For a given mix, the closer the aggregate spacing, the stronger the resulting concrete. Closer aggregate spacing can be achieved by compacting dry ingredients instead of ingredients to which a minimal amount of water has already been added.
- Confinement of a dry mix prior to hydration helps keep particles together during the hydration process, and this counteracts the hydrostatic pressures that work to drive particles apart when excessive water is brought into a mix.
- The main advantage that normally-hydrated concrete has over *in situ* hydrated concrete is that mixing ingredients after adding water helps disperse cement particles more uniformly throughout the mix. Research is needed to assess methods for producing dry concrete mixes that will be characterized by a uniform dispersion of cement after being compacted into forms/molds.
- Compressive strength of a concrete specimen decreases if its moisture content is uniformly increased throughout its volume.
- Additional research is necessary to determine how *in situ* hydrated concrete strength is affected by aggregate properties, initial compaction, confinement pressure, dry mix uniformity after placement, as well as conditions related to water movement into the confined mix.

Engineering Properties of Connections with Multi-Type Fasteners

D.R. Bohnhoff*, N.P. Ryan, R. Thiel

Funding: UW Biological Systems Engring.; WIs. Frame Builders Assn.; Walters Building Systems

The National Design Specifications for Wood Construction requires that design values for mixed fastener connections be based on tests or other analysis. This poses a problem for many post-frame building designers who have traditionally featured a combination of nails and bolts in their post-to-truss connections.

The goal of this study is to develop design methodology for connections featuring both nails and bolts. The approach involves a combination of laboratory testing and theoretical development. The latter will investigate yield theory equations for mixed fastener connections.

Laboratory testing began in December 2002 and involves double shear connection tests. A third of the specimens are nail-only joints, one-third are bolt-only joints, and the remaining third features both nails and bolts. Each test specimen consists of three 9.25- by 9.25-inch blocks (a main member and two side members) cut from nominal 2- by 10-inch dimension lumber. Four different test configurations are obtained by orienting the grain of the side and main members either perpendicular or parallel to the direction of applied load. All three configurations are being tested (per-per, par-par, par-per). This is not typical. Most connection studies feature only per-per or par-par tests (i.e., the grain of both side and main members run in the same direction, either perpendicular or parallel to the loading direction). In post-to-truss connections, however, members are perpendicular to each other. Consequently, connection tests in which the grain of the side and main members are perpendicular to each other are actually more appropriate for this experiment.

To study the influence of specific gravity on connection behavior, three different species of lumber were used to fabricate specimens: Southern Pine, Douglas Fir and Spruce-Pine-Fir. Testing will be completed during the spring of 2004 with data analysis to follow.

Accuracy of Corrugated Metal Panel and Trim Installation

D.R. Bohnhoff*, D. Cockrum

Funding: UW Biological Systems Engring.; Natl. Frame Builders Assn.

In 1999, the National Frame Builders Association (NFBA) published *Accepted Practices for Post-Frame Building Construction: Framing Tolerances*. In preparing this document, UW-Madison researchers conducted an extensive field investigation to determine just how accurately post-frame building frames are constructed.

This framing tolerances document was intended as the first in a series on post-frame building construction. The Technology and Research Committee of NFBA is now pushing for development of a second document focusing on installing corrugated metal trim and panels. As with the previous framing tolerances document, a field study must first be conducted to find out exactly how accurately such trim and panels are installed. As before, UW researchers will conduct this field investigation.

Data collection began in the summer of 2003 and should be completed by mid-summer 2004. To date, about 25 buildings have been surveyed. Items investigated include: (1) panel plumbness; (2) roof-to-wall panel rib alignment; (3) corner trim squareness; (4) corner trim connection to wall panel; (5) wainscot panel alignment; (6) roof panel offsets at eaves; (7) variations in roof panel overhang; (8) misalignment of wall panel ends (e.g., saw-tooth effect); (9) fit at openings; (10) dings; (11) scratches/scrapes; (12) crimps/kinks; (13) horizontal fastener alignment; (14) fastener driving depth; (15) fastener driving angle; (16) fasteners missing framing; and (17) irregular fastener patterns.

The goal of this research is to take measurements on about 50 different buildings, with no two surveyed buildings erected by the same crew. Results of this field investigation will be published once data collection is completed in 2004.

Post Installation Tools

D.R. Bohnhoff*

Funding: Wis. Frame Builders Assn.; UW Biological Systems Engring.

Embedded post foundations are largely responsible for the cost-effectiveness of the post-frame building system. However, like other foundation systems, their installation has its unique challenges. To help overcome some of these difficulties, prototypes of three different tools (a post hole leveler, a cookie cart, a post hole installation shield) were developed and tested in 2003.

A post hole leveler levels soil at the base of a hole prior to tamping and placement of a precast concrete footing (aka cookie). The use of such a device becomes increasingly important as footing diameter increases. Without such a device, it is difficult to ensure that the base of a hole is not tilted or uneven. A tilted base results in a tilted footing and, consequently, a significantly reduced area of contact between the footing and post. Uneven terrain (i.e., high and low points) results in more variant footing stresses and increases the likelihood of future foundation settlement. Key features of the UW-Madison Post Hole Leveler include cutting edges at 90 degrees to leveling/support "spokes", a centering/pivot point, and interchangeable heads to facilitate different size footings, storage and different soil conditions. The post hole leveler worked well in the sandy soils encountered on the test site. More rigorous testing is required.

A cookie cart is a device used to transport and lower a precast concrete footing (aka cookie). On virtually all jobsites, precast footings are dropped into post holes. Unfortunately, regardless of its size, the likelihood of a dropped footing landing properly in a hole is extremely remote. When one edge of a footing hits first, the result is a localized soil bearing failure, a failure involving the movement and loosening up of a good portion of the surrounding soil. The idea behind the cookie cart is to enable one single person to easily move and accurately lower even the largest of footings. On jobsites where workers have used a loader tractor, skid steer loader, or fork lift to lower footings, a cookie cart would free up this equipment and its operator for other tasks. Key objectives in the design of the UW-Madison Cookie Cart were minimizing its cost, weight, and transport size while maximizing its lift capacity. The UW-Madison prototype was built for less than $100 in materials (retail prices), has an empty weight of 98 lbs., and fits in a 16- by 28- by 40-inch box when folded for transport. Folding takes about one minute. Except for undersized wheels, the UW-Madison Cookie Cart worked very well when used to place 170- and 330-lb. footings. Wheelbarrow tires (which would have worked fine) were originally purchased but smaller, less expensive wheels were substituted during fabrication to reduce cost. Another prototype is planned. An option to allow powered lifting/lowering via a battery-powered screw gun may be incorporated into the new design.

The UW-Madison Post Hole Installation Shield (PHIS) is a device to keep holes from collapsing during hole auguring and post placement. Hole collapse is an issue in cohesionless soils or when drilling through non-compacted fill materials. Collapse likelihood increases as hole diameter and drilling depth increase. The UW-Madison PHIS consists of a 3-foot long split tube with a 26-inch inside diameter. The tube is placed approximately 2.5 feet below the original ground surface (half a foot remains above grade) after some initial auguring. The tube keeps soil from collapsing into the hole until auguring is completed. With the shield in place, workers level and compact the base of the hole, install the precast footing, plumb the post, brace the post, and compact soil around the post up to the base of the shield. At this point a fulcrum is clamped onto the post about 4.5 feet above grade. A long lever is placed over the fulcrum. Chains are then used to attach the lever to the shield. With the mechanical advantage designed into the system, an average sized person pulling down on the lever can withdraw the shield. (Note, this action helps set the post and footing.) Generally the chains must be rehooked a couple of times before the shield is entirely loose. Once loose, pins that hold the two tube halves together are removed, and the tube is split and pulled away from each side of the post. The UW-Madison PHIS worked flawlessly during initial testing. Additional testing in different soil conditions is planned.

Lateral Load Distribution in a Metal-Clad, Wood-Frame Building

D.R. Bohnhoff*, P.A. Boor, M.H. Gadani

Funding: USDA Hatch; USDA Natl. Research Initiative; UW Biological Systems Engring.; UW Graduate Sch.; Lester Building Systems

This project involved constructing and testing a full-scale, metal-clad, post-frame building with the goal of gaining a better understanding of the complex distribution of load in this popular agricultural building system. The building was erected, instrumentation was installed, and initial tests were conducted in 2001. Research in 2002 was dedicated entirely to testing and data analysis. Research in 2003 consisted of data analysis and computer modeling.

The test building is 40 by 200 feet with trusses on 10-foot centers. Trusses are pin-connected to posts, which, in turn, are pin-connected to concrete piers. Centered under each interior truss is a hydraulic frame loader (HFL) that is attached by rods to each end of the truss. An HFL can be set to operate in one of four modes: (1) north load, (2) south load, (3) lock, or (4) float. Although there are no HFLs under the endwall trusses, the endwall trusses can be either locked in place or allowed to float during a test.

Using the versatility of the HFLs, different loadings were applied to each of 10 different building configurations. Different building configurations were obtained by adding and removing: the ridge, chord reinforcing hardware, roof-to-sidewall fasteners, roof panel stitch screws, sidewall steel, and eave trim. In 2002, this experimental design was replicated twice for a total of 440 building tests. During each test, signals from 225 different transducers were recorded every 4.7 seconds. With a test time of at least 3 minutes, each loading usually generated at least 10,000 data points. This obviously is an unwieldy amount of data to analyze without significant data reduction.

Throughout early 2003, research effort was dedicated to data reduction. This was accomplished by first calculating an

average horizontal frame force for each 4.7-second scan. The second step was to linearly regress the output from each transducer on the average horizontal frame load values. After these regression analyses, the data file for each load case was reduced to 204 values. During the second half of 2003, research efforts were dedicated to developing computer models whose behavior under load accurately simulated test results. At this point, different models are being proposed and analyzed. In general, the building is modeled with a series of simple spring elements. Models differ in the number and arrangement of springs. Linear (and, in some cases, nonlinear) material properties are determined for the springs by assigning thousands of different combinations of properties to the springs and determining which combination produces a model whose behavior best mirrors that of the actual building under all test load cases.

Although the official termination date for this project has passed, assessment of building models will continue well into 2004. Once this work is completed, proposals will be drafted for major changes to ASAE EP 486, the current diaphragm design standard for metal-clad wood-frame buildings, and to ASAE EP 558, the current test procedure for metal-clad wood-frame diaphragms.

Fall Protection/Arrest Systems for Post-Frame Building Construction

D.R. Bohnhoff*

Funding: Wis. Frame Builders Assn.; UW Biological Systems Engring.

Fall protection is a primary concern on most construction sites, especially post-frame building sites. Unfortunately, many post-frame builders fail miserably when it comes to meeting OSHA fall protection requirements. This is generally due to a combination of factors including: lack of familiarity with OSHA requirements, difficulty interpreting OSHA requirements, misleading product literature, reluctance to implement time-consuming and/or expensive safety practices, and lack of fall protection systems that are both easy and safe to install.

In an attempt to improve safety on post-frame building sites, changes were made to a fall protection/arrest system developed and used by Lester Building Systems (LBS), Lester Prairie, MN. The UW-Madison version of the LBS fall protection/arrest system was fabricated and used on a construction site in Rhinelander, WI.

The LBS fall protection/arrest system consists of four primary elements:

1. Column jacks and associated scaffolding plank;
2. Horizontal "eave" lifelines and their supporting structure;
3. Horizontal "truss" lifelines and their supporting structure;
4. Full body harnesses with self-retracting lifelines and/or rope grab lanyards.

A column jack is a bracket attached to a post to support scaffolding plank. It is similar in design and identical in function to an OSHA-defined "carpenter's bracket" and an OSHA-defined "form bracket". The column jack developed at UW-Madison incorporates a quick-clamping feature for rapid attachment to a post. No tools, nails, screws, etc. are required to install it. Relative to other column jacks, the UW-Madison jack is structurally more efficiently designed and costs less to manufacture.

Horizontal "eave" lifelines are cables that are stretched approximately two feet above the top of each set of sidewall posts. Fall arrest lifelines are required any time someone is on a scaffolding system that: (1) is not fully enclosed with an OSHA-approved guardrail system, and (2) is more than 10 feet above a lower surface. The use of horizontal "eave" lifelines is unique to the LBS fall protection system. In reality, there are few options to the LBS system other than to fully enclose scaffolding with an OSHA-approved guardrail system. The major UW-Madison modification to the LBS fall protection/arrest system involved designing an adjustable frame system to support the horizontal "eave" lifelines. Structural analyses show that forces in horizontal lifeline (aka cable) support systems are significant and that the LBS system may not meet OSHA loading requirements when used on buildings with relatively high eave heights. While the UW-Madison cable support system can handle higher loads than the LBS cable support system, it is also considerably more massive and thus requires more manpower and time to install.

Horizontal "truss" lifelines are ropes that are anchored to the top chords of each truss before it is lifted into place. After a truss is installed, workers attach their lifelines to the "truss" lifelines for fall arrest while installing roof purlins. Each "truss" lifeline is attached to the truss with anchors located at the eave (aka heel) and ridge of the truss. Lifelines are detached from the truss heels once purlins have been installed. The anchor located at the ridge is used as a lifeline anchor when workers are installing roof sheathing. UW-Madison anchors were specially designed to be low cost, structurally sound, versatile, and easy to fabricate.

While the UW-Madison version of the LBS fall protection/arrest system functioned well, the support system for horizontal "eave" lifelines needs to be extensively tested. In addition, the mass of the frame support system needs to be reduced to make the system easier, and hence safer, to install.

Characteristics of Notched Purlins

D.R. Bohnhoff*

Funding: UW Biological Systems Engring.

In 2003, research was initiated on notched purlins fabricated from nominal 2- by 6-inch lumber. This research consisted of installing notched purlins in an actual building to determine associated construction advantages and laboratory testing to determine strength reductions associated with notching.

All purlins in this study had a total length of 9 feet, with a center-to-center distance between notches of 8 feet (i.e., they were designed for use on a building with an 8-foot truss spacing). Notch width was slightly less than 1.6 inches. Notch depth was such that 3 inches of wood remained at the notch. Although with a 5.5-inch deep member (i.e., a nominal 2- by 6-inch), this would typically translate to a notch depth of 2.5 inches. Each end of the purlin was tapered on the notch side so that the distance from the tapered edge to the bottom of the notch (i.e., notch depth) varied from 11/16ths to 13/16ths inches. It follows that tapering purlin

ends reduced notch depth to less than 1/4th the depth of the unnotched members at notch locations. While it was felt that this would significantly reduce stress concentrations at the notch, such tapering violates the lumber grade and increases the angle between the member edge and wood grain (i.e., tapering increases slope-of-grain).

As a preliminary investigation into how notching and tapering purlin ends affects shear strength, 14 No. 2 Southern Pine purlins were tested to failure in bending under a 1/3 point loading arrangement. In 7 of the 14 members, initial failure was associated with notching and tapering of the member ends. Initial failure in the other 7 members occurred in the constant bending moment region. Regardless of the failure type, the maximum bending stress at failure was calculated. Interestingly, the average bending stress values for the notch failure group and non-notch failure group were virtually identical (6440 and 6760 psi, respectively). However, the COV of the bending stress values at failure were significantly higher for the non-notch failure group (40% versus 25% for notch failure group). The higher the COV, the lower the design properties, which means that for the batch of lumber used in this study, notching and tapering of the member ends would not control in situations where a member was subjected to a uniformly distributed load.

Use of notched purlins increases construction safety, speed, and accuracy, and results in purlin-to-truss connections that can transfer high chord forces without supplemental steel reinforcement. Construction safety begins with the pre-drilling of holes for nail fasteners at the same time purlins are notched and tapered. Pre-drilling is possible because notch location dictates nail location. Safety is enhanced because pre-drilled nails can be partially driven on the ground. Safety also results because pre-driven nails help secure lines that are slipped over purlin ends for lifting purposes. Pulling purlins onto a roof with a tag line is considerably safer than having them tossed up from the ground (a common occurrence). Reaching for a thrown purlin increases likelihood of a fall, and a thrown purlin is a dangerous flying object, especially if it doesn't reach its mark. On the roof, notched purlins are considerably easier to position. The notch also helps hold the purlin in place while nails are driven home. This, and the fact that nails are already started, means a worker has one hand free which can be used for greater personal stability. Also, because of pre-driving, less nailing energy is expended by workers maneuvering around on the roof framing. It follows that notched purlins and pre-drilling nail holes improves construction accuracy. Notches lock in truss spacing. Pre-drilling nail holes ensures that nails penetrate the center of a rafter/truss top chord. Improvements in construction speed result because truss spacing is quickly and easily fixed, nailing is faster, and the use of lifting lines keeps construction smooth and continuous.

Notching enhances the transfer of both tensile and compressive chord forces between purlins in adjacent bays. Since purlins in adjacent bays are both locked to the truss between them, any axial force in one purlin will be transferred via notches and nail connections to the other purlin. Transfer of measurable tensile chord forces is frequently a problem with purlins that rest in joist hangers. Such purlins must generally be tied together over the top of the truss with special metal strapping. Also note that by decreasing the depth of a purlin at a notch, shorter nails can be used to attach the purlin to the truss, and purlin roll forces that work to bend such a connection are reduced.

Future work on notched purlins will involve finite element analysis and laboratory testing with dimension lumber and engineered lumber products. It is important to note that tapering is not a major issue with products such as laminated strand lumber (LSL) since tapering of such products does not violate lumber grade nor increase slope-of-grain. In the end, a notched purlin may be a hybrid product with LSL ends finger-jointed to a dimension lumber midsection.

Steam Stabilization of Aspen Fiberboards

R.M. Rowell*, S. Lange, J. McSweeny, M. Davis
Funding: USDA Forest Service

Many techniques have been used over the years to dimensionally stabilize wood fiber composites against the swelling forces imparted when the fiber is compressed during fiberboard formation and when the fiber sorbs moisture after board formation. When a compressed fiber sorbs moisture, not only does reversible swelling take place (normal swelling of the fibers resulting from sorption of moisture), but the compressive forces imparted when the fibers are crushed in the board upon pressing (irreversible swelling) are relieved due to recovery of the original configuration through a cell wall memory.

Applying high temperature steam during fiberboard pressing, and cooling fiberboard while still under pressure, can greatly increase its dimensional stability. After pressing for four minutes at 200°C under steam pressure, aspen fiberboard showed less than 10% thickness swelling after a two-hour water soak as compared to more than 40% for non-steamed fiberboard. The stabilized boards were re-fiberized and a phenolic resin was added. The fibers were then hand formed into a mat and pressed into fiberboard again. Swelling in water of these phenolic-bonded boards was about the same as boards with no adhesive, but strength properties improved when the adhesive was used.

Development of Advanced Wood Fiber-Based Composites Based on Fiber Modification

R. Ibach, S. Lange, R.M. Rowell*
Funding: USDA Forest Service

The performance of wood fiber-based composites can be greatly improved by chemical modification of the fiber from which the composite is made. Dimensional stability and water repellency can be greatly improved by bulking the cell wall with bonded chemicals and by using hydrophobic reactants. Decay resistance can be greatly improved using the same chemistries since restricting access to water by micro-organisms is one way to stop or decrease fungal attack.

One technology that has been studied is the reaction of wood with acetic anhydride. Dimensional stability of acetylated wood is greatly increased as is decay resistance. This is a non-toxic approach to wood preservation that is presently under commercial development.

Development of Wood Fiber-Thermoplastic Composites

D.F. Caulfield, R. Jacobson, R.M. Rowell*

Funding: USDA Forest Service; two US companies

Research continues on the development of wood fiber-thermoplastic composites. Polyethylene, polypropylene and nylon are being compounded with or without a compatibilizer. Different concentrations of wood fiber are being used as well as different types of mixing technologies. Compression molded and extruded specimens are tested for modulus of rupture, internal bond, and toughness to determine the effects of processing variables and composition variables.

Development of Fire Retardant Wood Fiber-Based Composites

G. Chen, R.M. Rowell*

Funding: USDA Forest Service; one US company; one foreign company

In the chemical modification research program, reactive fire retardants are used to bond a reagent to wood cell wall hydroxyl groups that decrease the thermal decomposition temperature and increase the char residue. Nitrogen-phosphorus containing reagents are being used, and the results show an increase in flame retardency as well as an increase in biological resistance.

Development of a Rapid Test for Heavy Metal Ion Removal Using Wood Fiber

S.H. Min, P. Kmiecek, J. McSweeny, R.M. Rowell*

Funding: USDA Forest Service

In order to determine the relative efficiencies of different types of lignocellulosic fibers in their ability to remove heavy metal ions from solution, a simple static sorption test is being developed. A standard weight of a known particle size is placed in a known concentration of a standard heavy metal (copper, in this case) and shaken at room temperature for 24 h. At the end of this time, the amount of copper ion left in solution is measured and the efficiency determined.

High Performance Wood Composite Materials through Activation Bonding

F.S. Denes*, R.A. Young, S.O. Manolache, L.E. Cruz-Barba, V. Totolin

Funding: McIntire and Stennis Grant

Wood-based composite materials, such as particle boards and fiberboards, are produced from disintegrated waste wood materials. The generation of high-quality composite materials strongly depends on the adhesion between the wood substrate surfaces and the adhesive materials.

The main objective of this research is to use plasma-aided technology to modify both wood and lignin-particle surfaces and to generate specific surface functionalities that will enhance adhesion characteristics. Powdery lignin substrates were exposed separately to both argon- and formaldehyde-plasma environments in a rotating glass plasma reactor and reacted under *in situ* conditions with epichlorohydrin and consecutively with ethylenediamine using *ex situ* reactions. Wood chips were also treated under formaldehyde-plasma environments using a parallel-plate, RF-static plasma reactor.

Results from these investigations indicate that the cold plasma technique is an efficient approach to modify the surfaces of lignin and wood substrates.

Safety and Health

Mixing and Loading Facility Design Specifications

D.W. Kammel*

Funding: Wis. Dept. of Agric., Trade, and Consumer Protection

The Department of Agriculture, Trade, and Consumer Protection is in the process of updating rules for the bulk storage, mixing and loading of fertilizers and pesticides at commercial operations. Current recommendations on function system design and construction must be updated as well. This project involves editing and updating the appropriate sections of the publication *Designing Facilities for Pesticide and Fertilizer Containment (MWPS-37, copyright 1991*) for use as the appendix that will accompany the new rules. This material will be of help to facility managers and designers to help in the design process and construction details for building properly designed facilities.

Wisconsin Dairy Traumatic Occupational Injury Intervention

L.J. Chapman*, A.C. Newenhouse, K.G. Josefsson, M.G. Miquelon, K.M. Pereira

Funding: US Centers for Disease Control and Prevention; Natl. Inst. for Occupational Safety and Health

Cooperators: UW Biological Systems Engring.; various Wis. dairy organizations; UW Coop. Ext. Service

This project will implement and evaluate the effectiveness of an intervention in the workplace intended to prevent and reduce traumatic agricultural injuries. We will build on our ongoing intervention among the 21,000 Wisconsin dairy operations that constitute 20% of the nation's operations and employ more than 73,500 workers. Our intervention strategy will encourage adoption of production practices that are more profitable as well as safer. The work methods and equipment used in a dairy operation largely determine what hazards the workforce is exposed to. The operation's manager largely determines the work methods and equipment used. Our intervention improves information flow to these managers to persuade them to adopt certain production methods that should improve safety as well as maintain profitability, thereby reducing traumatic injuries.

We plan to accomplish three specific aims.

1. Continue, for three additional years, a community-based information dissemination intervention among Wisconsin dairy producers that will reduce traumatic injuries by persuading operation managers to adopt safer, more efficient work methods. We will reduce hazards (and thereby injuries) by improving information flow to operation managers to persuade them to adopt production methods that are both safer and more profitable. We will continue this theory-based intervention with a specially-designed information dissemination effort that uses sources that dairy producers already rely on for information about new production methods (e.g., other farmers, print media, public events, university Extension personnel, other private and public sector resource people, and the Internet).
2. Conduct annual, large-sample, mail questionnaire-based scientific evaluation of the information dissemination intervention that includes both process and outcome measures. We plan to refine and continue, for three additional years, to administer mail questionnaires that tap both process and outcome measures to separate, population-based, rolling probability samples of the study group (n=800/yr) and a control group (n=400 Maryland farmers/yr). We intend to determine:
    a) if our materials are reaching the target audience and which intervention aspects are most effective, and
    b) whether producer adoption and awareness of each production method have increased.

We will gather information about injuries, barriers to adopting the production methods, and how to make our intervention effort more persuasive.
3. Add one or two traumatic injury-reducing production methods to the intervention in each of the three additional intervention years. We will seek out reports from farmers and others about emerging production methods that could improve safety and profits. We will evaluate hazard-reducing and profit-enhancing aspects of the best production methods. We plan to add one or more of these new production methods with the clearest labor-saving and injury-reducing advantages to the intervention to promote statewide.

Community Partners for Healthy Farming Nursery Field Crop Growers Intervention Project

L.J. Chapman*, A.C. Newenhouse, M.G. Miquelon, K.G. Josefsson

Funding: US Centers for Disease Control and Prevention; Natl. Inst. for Occupational Safety and Health
Cooperators: UW Biological Systems Engring.; various Wis. grower organizations; UW Coop. Ext. Service

This project will accomplish three specific aims.

1. Develop or identify existing control technologies for work performed by Midwestern nursery operations engaged in bedding and garden plants and nursery crop production. We will reduce hazards (and thereby injuries) by developing or identifying controls that reduce exposure to physical work hazards for musculoskeletal and traumatic injuries. The types of controls we will consider include work practices, tools, labor aids, and administrative controls. We will seek out reports from nursery managers, commercial suppliers, university Extension personnel, and others about emerging production practices that could improve both safety and profits. We will also collaborate with university instructors and their students in design and other engineering courses to accomplish this aim.
2. Conduct field research to evaluate the control technologies from #1 above which show the most promise to determine their impact on production and to verify that musculoskeletal risk factors are actually reduced when the practices are adopted. We will undertake small-scale field studies to quantitatively evaluate the hazard-reducing and profit-enhancing aspects of two to four of the best production practices each year. Comparisons will be made in the field or in laboratory situations between accomplishing work by conventional methods and with the improved control technology. Fewer than six subjects in each condition for less than half a day of work are anticipated. Small-scale field studies will also be undertaken on operations that have adopted practices to verify that musculoskeletal risk factors are really reduced.
3. Conduct and evaluate a large, region-wide intervention to promote the best control technologies from #2 above to the 7,888 nursery operations in seven north central states (WI, MN, MI, IA, IL, IN, OH) that produce bedding and garden plants and nursery crops. Disseminate information about the improved work practices through sources that growers already rely on for information about new production methods (e.g., other growers, trade publications, public events, university Extension agents, other private and public sector resource people, the Internet, etc.) Evaluate the interventions with annual mail questionnaires to separate, population-based, rolling probability samples of the study group (n=650 nursery growers/yr) and the control group (320 New Zealand nursery growers/yr).

Electric Power and Energy Systems

Atmospheric Pressure Non-Equilibrium Plasma (AP-NEP) Modification of Gasoline Composition

F.S. Denes*, S.O. Manolache, N. Hershkowitz

Funding: UW Mechanical Engring.; General Motors Corp.; UW Ctr. for Plasma-Aided Manufacturing; UW Biological Systems Engring.

The objective of this project is to develop AP-NEP installations that can be in-line incorporated into the gasoline supply lines of combustion engines and plasma technologies for controlled modification of gasoline composition. Prototype installations were developed and tested, including the power supply built up of car-ignition device components. Preliminary data indicate that normal- and iso-octane molecules can be fragmented, and both lower and higher molecular weight hydrocarbon derivatives can be produced. Research is underway to evaluate plasma parameters for generating ether- and peroxy-type compounds. It is presumed that lower molecular weight hydrocarbon fractions and oxygen-containing structures could increase the burning efficacy of gasoline in combustion engines.

A Study to Evaluate the Impacts of Increasing Wisconsin's Renewable Portfolio Standard

P.D. Thompson*

Funding: Wis. State Div. of Energy

Cooperators: UW Biological Systems Engring.; Wis. State Div. of Energy; Wis. Public Service Comm.; Union of Concerned Scientists; Sustainable Energy Advantage; LaCapra Assoc.

A final report was completed and provided to the State of Wisconsin Division of Energy on Sept. 11, 2003. Four scenarios were modeled of future requirements for percent renewable content in electric power sold by Wisconsin utilities. These ranged from continuing the present standard (2.2% renewables by 2010) up to raising the requirement to 10% by 2013. Even under the most aggressive scenario and under the worst case assumptions that there would not be sufficient transmission capacity to import renewable-sourced power into the state and that the present Production Tax Credit for renewables would not be extended, the projected monthly cost of electric power for the average Wisconsin household should rise only $0.51/mo. If the Production Tax Credit was extended and imports were not restricted by available transmission capacity, costs could actually drop $0.16/mo. A 10% Renewable Portfolio Standard would lead to 2,200 MW of renewable generating capacity being brought on line, producing 8.6 trillion kW hours annually by 2013. Economic projections indicate that most new capacity will come from wind generation, with lesser amounts from biomass and other renewable sources. Carbon dioxide emission reductions could be more than 7 million tons annually, regardless of technology.

Exposure of Dairy Cattle to Electrical Events and Their Biological Consequences

D. Alumbaugh*, L.G. Sheffield, D.J. Reinemann

Funding: Wis. State Legislature

Cooperators: UW Civil and Environmental Engring.; UW Dairy Sci.; UW Biological Systems Engring.

This project will employ the magnetotelluric (MT) method to estimate the strength of electric currents generated in the earth by man-made sources including those originating from an electric power distribution system. The MT method measures naturally-occurring electromagnetic fields to investigate the earth's electrical properties. Traditional examples of using MT data analysis include oil, mineral, and groundwater exploration.

Using a biological method known as array hybridization, we will assess the impact of electrical exposure on messages produced in the immune system. This method allows us to assess several thousand messages in a single sample. Unlike other studies in which relatively few measurements are taken, we will be able to assess essentially every messenger RNA produced in a tissue. This greatly reduces the chances of missing potentially important measures because they were not included in a study. Because message production in the immune system is a critical link between the environment and a cow's health, such measurements provide critical information about the impact of electrical exposures on dairy cattle.

Agricultural Energy Management Assessment System

D.J. Reinemann*, S.A. Sanford, E.A.R. Bird

Funding: Wis. Focus on Energy

Cooperators: UW Biological Systems Engring.; UW Soil Sci.

This project will develop and test agricultural energy management assessment support materials. Energy management tools will be developed with various levels of technical detail targeted at specific user groups. A simple self-assessment tool will be developed for producers and will be available as a web-based tool. This interactive agricultural energy management assessment system will be incorporated into the Farm•A•Syst and Wisconsin Environmental Management Assessment programs as well as the Wisconsin Focus on Energy local energy service provider resources website, www.focusonenergy.com. More detailed energy audit tools will be developed for energy service providers. The program will be piloted in several counties in which energy auditors and county Extension agents will be trained in the use of these tools. Programs will be offered at Wisconsin Farm Technology Days and at regional seminars.

Farm Energy and Stray Voltage Program

D.J. Reinemann*, M.A. Cook, R. Kasper, J. Roberts, D. Hansen

Cooperators: UW Biological Systems Engring.; Wis. Public Service Commission; Wis. Dept. of Agric., Trade, and Consumer Protection

The objective of this program is to promote safe, efficient use of electrical energy in rural areas. Issues addressed include energy conservation and load management technologies for farms and food processing plants, electrical safety and power quality on farms, detection and mitigation of stray voltage, renewable energy sources, and distributed generation prospects for farms. Educational activities include the following:

- Presentations at Wisconsin Farm Technology Days and other agricultural events;
- Presentations at county, state, and national seminars;
- Support of Midwest Rural Energy Council educational efforts;
- Stray Voltage Investigators Training courses;
- Support of other state agencies with rural energy activities.

Food Engineering and Processing

Plasma-Enhanced Synthesis of Surface Layers that Kill Bacteria on Contact

F.S. Denes*, S.O. Manolache, A.C.L. Wong

Funding: CSREES Natl. Research Initiative, Food Safety

This project started in December 2003. Quaternary ammonium and phosphonium functionalities will be implanted onto various substrate surfaces using cold plasma technologies. The antibacterial characteristics of the modified substrates will be evaluated.

Development of Atmospheric Pressure Plasma Technologies for Efficient Decontamination and Disinfection (Including Spores) of Surfaces, Air and Water

F.S. Denes*, S.O. Manolache, A.C.L. Wong

Funding: UW Ctr. for Plasma-Aided Manufacturing; UW Biological Systems Engring.; US Office of Naval Research; UW Food Research Inst.; Amer. Meat Inst.; Wis. Energy Ctr.

It was shown that under specified dense medium plasma (DMP) reactor experimental conditions, more than 10^5 bacteria/mL of *Listeria monocytogenes* or a bacterial cocktail of 16 different environmental isolates are inactivated in 10 s at power consumption as low as 200-300 W. It was also shown that aromatic contaminants of 600-1000 ppm concentration are reduced to 2-3 ppb in only 25 s. If nascent colloidal silver particles are present in the contaminated water, disinfection is even more efficient. (Colloidal silver nanoparticles can be generated simultaneously with the plasma process by using silver electrodes.) Experiments are underway to evaluate the efficacy of the DMP system for disinfecting fresh orange juice.

The array electrode reactor (AER) allows efficient disinfection of various static or moving substrate surfaces such as metals, glass and polymers. Potential applications include disinfecting conveyor belts and cutting blades. The AER can also disinfect incoming or recycled air, which opens up a novel route to develop advanced technologies to eliminate aerosol-based contamination in ready-to-eat food processing locations. Preliminary tests indicate that bacteria mixtures and highly-resistant spores deposited on stainless steel coupon surfaces can be annihilated under both air and oxygen AER plasma environments with treatment times as short as two minutes.

Future research will focus on understanding the discharge-induced reaction mechanisms responsible for killing bacteria and spores and on optimizing plasma parameters and data acquisition to evaluate possible scaling-up of plasma technologies for industrial applications.

Fundamental Studies of Atmospheric Pressure Plasma-Enhanced Decontamination and Disinfection of Water. Dense Medium Plasma/Array-Electrode Reactor (DMP-AER), a Novel Approach to Naval Wastewater Treatment

F.S. Denes*, S.O. Manolache, A.C.L. Wong

Funding: US Office of Naval Research

DMP and DMP-AER reactor systems were tested for decontaminating and disinfecting water. The efficacy of plasma tools was demonstrated. It was shown that levels of organic contaminant in water as high as 600-1000 ppm can be reduced to ppb concentrations in plasma-treatment times as short as 20-40 s. Using various DMP electrode materials (e.g., stainless steel, iron, titanium, copper, silver), the disinfection efficiency of the DMP system was tested with artificially contaminated water. The strong disinfecting capability of DMP environments was demonstrated, and the importance of the metal and metal oxide nanoparticles dispersed into water during the disinfection process was emphasized.

Dense Medium Plasma (DMP) Synthesis of Hybrid Iron/Iron-Oxide and Carbon-Based Magnetic Nanoparticle Systems with Applications in the Area of Targeted, Localized Anti-Cancer Drug Delivery

F.S. Denes*, S.O. Manolache, Y. Ma, D.H. Thamm, I.D. Kurzman, D.M. Vail

Funding: UW Univ.-Industry Relations; UW Ctr. for Plasma-Aided Manufacturing; UW Biological Systems Engring.
Cooperators: UW Sch. of Veterinary Medicine; UW Comprehensive Cancer Ctr.

Using DMP technology, carbon magnetic nanoparticles (CMNP) were synthesized at room temperature and atmospheric pressure. Based on results from X-ray photoelectron spectroscopy, Fourier transform infrared spectroscopy, and scanning electron microscopy, we conclude that the nanoparticles are spherical, 40-50 nm in diameter, with iron/iron oxide particles dispersed in a carbon-based host-structure. Thermal gravimetry/differential thermal gravimetry analysis shows these nanoparticles are stable to temperatures as high as 600°C. The synthesized CMNP were treated by argon-plasma, aminated with ethylene diamine, and subsequently activated by generating aldehyde groups on them. Free doxorubicin (DOX) molecules were then immobilized onto the surfaces of activated CMNP particles to form CMNP-DOX conjugates. The corresponding loading efficiency was determined. The *in vitro* antiproliferative activity of immobilized DOX in the conjugates was demonstrated in tumor cell cytotoxicity assays. It is suggested that this CMNP-DOX system can be used for targeted drug delivery systems.

Plasma-Enhanced Deposition of Antifouling Macromolecular Layers on Material Surfaces Usually Involved in Food Processing Technologies

F.S. Denes*, S.O. Manolache, A.C.L. Wong, H. Jiang, B. Dong, Y. Wang

Funding: USDA Natl. Integrated Food Safety Initiative; Hatch
Cooperator: UW Food Research Inst.

If bacteria attach to surfaces, biofilms may form and create economic and health problems in many settings, including those of food and medical industries. Developing new technologies to prevent or at least attenuate biofilm formation is highly desirable.

In this study, plasma-enhanced deposition of polyethylene glycol (PEG)-type structures are examined as possible antifouling materials, and the resulting antifouling mechanisms are investigated. PEG chains are highly flexible and can cause an intense entropic repulsion of protein molecules due to reduced degrees of confirmation freedom of protein macromolecular chains. PEG is also highly water-soluble and, as a result of hydrogen bonds created between the oxygen atoms of PEG and water molecules, a water molecule-based shield is created around PEG macromolecular chains that may contribute to their antifouling behavior.

Three different approaches were considered for depositing PEG-type layers onto stainless steel and silicon rubber surfaces.
1. Deposit thin layer PEG-type networks from various plasma-generated, charged and neutral, volatile, precursor molecular fragments.

2. Graft PEG molecular chains onto $SiCl_2H_2$-, H_2-, and $SiCl_4$-plasma-functionalized surfaces.
3. Generate antifouling layers by cross-linking predeposited PEG structures under oxygen-, argon-, and radio frequency-plasma environments.

It was shown that all plasma-deposited PEG-type structures exhibit significantly reduced bacterial attachment and biofilm formation in the presence of a mixed culture of *S. typhimurium*, *S. epidermidis*, and *P. fluorescense*. Biofilms developed on these coated surfaces were less stable and easier to remove than those on uncoated surfaces. Future research will involve optimizing plasma-deposition processes to generate highly effective antifouling layers. Antifouling characteristics will be related to the chemical nature and morphologies of PEG-type structures.

Recently it was demonstrated that PECVD-deposition of diamond-hard carbon thin layers can accommodate biologically active layers. The characteristics of these layers are being investigated to evaluate their potential applications in preparing robust bio-active surfaces.

Design, Development and Testing of Novel Atmospheric Pressure Plasma Installations with Potential Scaling-Up Possibilities for Pilot and Industrial Technologies

F.S. Denes*, S.O. Manolache

Funding: UW Ctr. for Plasma-Aided Manufacturing; UW Biological Systems Engring.; Amer. Meat Inst.
Cooperator: UW Mechanical Engring.

Three original (patents and patent disclosures) atmospheric pressure (AP) plasma reactors were designed and developed by the Center for Plasma-Aided Manufacturing (C-PAM) and the Biological Systems Engineering Department. The reactors are the dense medium plasma (DMP) reactor, the array electrode reactor (AER), and the barrier discharge reactor for small dimension cavities (BD-SDC) and the flat-plasma ceramic reactor.

The DMP reactor is based on a digitally controlled, rotating, interchangeable pin array electrode system which generates a volume character of the plasma processes due to the presence of an intense cavitation developed in the reaction media. It can be operated using DC or AC power, and it allows extremely efficient modification of various liquid media (e.g., solutions, suspensions, etc.) in the presence of inert or reactive gases.

The AER installation eliminates the drawbacks of conventional AP gas-phase techniques by using a multi-cylinder/wire electrode array system which allows plasma exposure of various substrates under static or continuous flow system conditions. This electrode configuration assures a uniform flow of plasma gases or gas mixtures through a multitude of cylindrical individual discharges. With the AER, both metal and dielectric materials can be surface-treated uniformly, while the presence of a low dimension gap between the electrode system (usually associated with conventional AP reactors) is not required.

With the BD-SDC tools, electrical discharges can be generated in low dimension dielectric cavities, channels or capillaries by adapting a special electrode/cavity configuration. Embedding the electrodes into dielectric materials and maintaining a certain position of the cavity or capillary or channel volumes relative to these electrodes, AP discharges can be initiated and sustained in capillaries with inner dimensions smaller than 1 mm under batch- or continuous-system modes.

A Novel Plasma-Enhanced Way to Deposit Diamond-Hard Carbon Thin Layers under Atmospheric-Pressure and Room-Temperature Environments

F.S. Denes*, S.O. Manolache, L.E. Cruz-Barba

Funding: UW Ctr. for Plasma-Aided Manufacturing; UW Biological Systems Engring.

Our recent experimental results prove that predeposited high molecular weight C-, H- and O-, and C- and H-based polymer thin layers, and even surface layers of similar solid-state polymeric substrates, are converted under SF_x and protons (generated under SF_6 and H_2 plasma environments) into "diamond-hard" carbon layers at low or atmospheric pressure conditions and room temperature in plasma-conversion times as low as 2 to 4 minutes. These findings open up a very attractive, novel way to synthesize scratch- and wear-resistant large-area surfaces with applications in the fields of advanced biosensors and bio-active materials.

Mixing and Simulation Research

R.K. Connelly*

Funding: UW Foundation

Mixing is a particularly complex operation which is difficult to model due to the complex geometry and motions involved. An ideal tool to define flow and mixing in a mixer is numerical simulation in combination with particle tracking, which calculates the velocity, pressure, and stress fields from the fundamental physics that describes the behavior of the system and uses that information to calculate particle trajectories and field parameters that describe the flow conditions and mixing ability. The power of current computer hardware, such as the SGI Octane with dual processors, and the efficiency of current Computational Fluid Dynamics (CFD) commercial software packages, such as Fluent (FVM) and Polyflow (FEM) distributed by Fluent, Inc., now available in my lab have increased to the point that simulation of the flow and mixing in realistic mixers in 3-D is entirely possible.

The Finite Element Method CGD package Polyflow is being used to investigate mixing in highly viscous systems that fall into the laminar flow regime. Mixing systems where the flow domain can be fixed in time such as single screw extruders will be investigated with both generalized Newtonian fluid models and viscoelastic fluid models. Mixing systems with transient flow domains due to moving parts such as the Mixograph will be modeled using a mesh superposition technique.

The Finite Volume Method CFD package Fluent is ideally suited to investigate processes in the turbulent flow regime, with a wide range of turbulence models available. Currently a collaborative project is underway with Muthukumar Dhanasekharan of Fluent, Inc. and Richard Hartel of UW Food Science to model lactose crystallization in a continuous MSMPR cooling crystallizer using this software package.

Investigation of the Effect of Mixing Intensity on Dough Development and Rheological Property Measurement

R.K. Connelly*

Funding: USDA Hatch

Wheat is one of the most important crops grown in the U.S., with 67.1 million acres planted and a total harvest of 2.34 billion bushels in 2003. Wheat is an increasingly important commodity in Wisconsin, with acres planted rising by nearly 60% during the last five years to a total of 212,000 and an excellent harvest of almost 12.3 million bushels in 2003. Wheat is mainly used to produce flour for bread, baked goods and snack foods. The strength of wheat flour is a critical property related to its ability to develop and retain desirable product properties during processing and is a function of the variety and growing conditions. It must be considered by breeders, growers, millers and processors alike in order to insure proper flour selection and consistent final product quality for consumers. Mixing is a universal processing operation that must take flour strength into account and can be used to demonstrate it. However, the two most common mixing flour testing instruments, the Farinograph and the Mixograph, do not always give the same information because they use entirely different speeds, geometry and mixing actions, with resulting differences in the mixing intensity. What is needed to better understand and evaluate the results generated by these two mixers is a more thorough understanding of the rate, type and range of strain experienced by material as it is tested. The main focus of this work is to explore the links of rate and type of strain to dough development for Wisconsin-grown hard and soft winter wheat flour in both the Mixograph and Farinograph. Once the mixing environment is better understood, the relationship of the flour properties to the results can be better determined and the differences between results from the two instruments can be explained, leading to more reliable information for selecting appropriate flours, formulations and processing parameters for a given product.

Plasma-Induced Modification of Xanthan Gum

S. Gunasekaran, F.S. Denes*, S.N. Jampala

Funding: S.C. Johnson and Sons, Inc.; Hatch; UW Biological Systems Engring.

Xanthan gum (XG) is one of the most popular polysaccharides in food and bioprocess industries. XG has a negative charge and size similar to many other polysaccharides of interest in bioengineering. If XG can be modified in a controlled manner, several end-use applications can be improved. Cold plasma technologies open up novel, efficient routes to modify natural polymeric materials. The hydroxyl groups on the primary and secondary carbon atoms offer opportunities to incorporate new and useful properties. Because energy levels of plasma species are comparable to bond energies of common organic compounds, surfaces exposed to plasma species can be conveniently modified/functionalized under selected discharge parameters. Our objective was to investigate the effect of various cold plasma treatment parameters on implantation of additional functionalities onto XG structure.

The surface chemistry of argon (Ar) and oxygen (O_2) radio frequency (RF) plasma-treated XG under various external plasma treatment conditions was studied. XG was also functionalized under 13.56 MHz RF-SiH_2Cl_2-plasma conditions and consequently *in situ* aminated by ethylene diamine. Survey and high-resolution X-ray photoelectron spectroscopy (ESCA), fluorescamine labeling technique, FTIR analysis, residual gas analysis, and scanning electron microscopy (SEM) were performed to examine the treated XG surface morphology. ESCA spectra of Ar-plasma treated samples indicated an increase in surface areas of O-C=O and O-CO-O. O_2-plasma treated surfaces indicated a significant increase in O-C-O concentration. The modification took place even at low pressure and low power conditions and was not greatly influenced by external plasma processes. ESCA spectra show the presence of C-Si and C-N in SiH_2Cl_2-plasma treated and subsequently aminated samples. The intense brightness of functionalized XG in fluorescamine labeling indicated the presence of primary amine groups. FTIR measurements supported the ESCA observations. SEM images revealed several chunky and coated granule structures.

Cold plasma reaction is an efficient non-enzymatic way to modify industrial polysaccharides. This will lead to creating new and improved functionalities.

Changes in Cheese Microstructure during Melting

S. Gunasekaran*, S. Ko

Funding: Krenz Funds

Basic techniques were developed to investigate the time-resolved, *in situ* 2D and 3D characteristics of cheese during melting using confocal laser scanning microscopy (CLSM). *In situ* acquisition and processing steps of images from CLSM were studied to obtain microstructural characteristics during cheese melting. Computational image processing was introduced to remove errors and restore distortions during image acquisition and experiment. This was focused on minimizing errors to obtain reliable, reproducible data. With 3D reconstruction techniques, 3D visualization characterized fat globules and the related melting behavior. These principles and basics may not be restricted to a specific cheese system but extendable to various ones.

Effect of Heating Rate and Xanthan Addition on Gelation of Whey Protein

S. Gunasekaran*, M.M. Ould Eleya, J. Li

Funding: Dairy Mgmt., Inc.; S.C. Johnson and Sons, Inc.

The effects of heating rate and xanthan addition on gelation of 15% w/w whey protein isolate (WPI) were studied at pH 7, 0.1 M phosphate buffer solution. Small amplitude oscillatory shear tests were performed to investigate the rheological properties of WPI gel. WPI was heated from 25 to 90°C at different

heating rates (0.1, 1, 5, 10, 20°C/min). Gelation temperature of WPI decreased with decreasing heating rates. In the presence of xanthan, WPI gelled at lower temperatures compared to WPI without xanthan addition. WPI gels 15% w/w and WPI 15% w/w-xanthan (0.1%, 0.2%, 0.5%, 1% w/w) mixed gels were prepared using a controlled heating system. The cylindrical gels were formed from 25 to 90°C at different heating rates (0.1, 1, 5, 10, 15°C/min). Uniaxial compression tests were used to characterize the mechanical properties of gels at 25°C. If xanthan content was no more than 0.2% w/w, WPI gels exhibited brittle characteristic. The fracture stress of gels was higher when they were prepared at lower heating rates. When the xanthan content was increased to 0.5% w/w, WPI gels exhibited ductile characteristic.

Functionally-Modified Egg White Albumen Hydrogel

S. Gunasekaran*

Funding: S.C. Johnson and Sons, Inc.

Hydrogels were prepared using egg white albumen (EWA) before and after chemical modification of its lysyl residues with ethylenediamine acetic dianhydride (EDTSD) to incorporate carboxylic groups. This resulted in an increase in swelling ratio of EWA hydrogels. The swelling ratio increases dramatically in deionized water, substantially more so than in the pH 7.4 buffer solution. The effects of medium pH, temperature, and swelling were investigated along with crosslinking of the gel network by glutaraldehyde (GLA) as well as acetone treatment. The gels denatured by acetone showed an insignificant increase in swelling ratio for the gels crosslinked with GLA during gel preparation, which is in contrast to the gels crosslinked subsequent to gel formation. The medium temperature and swelling time had a positive effect on the swelling. However, an insignificant effect of pH was observed due to electrostatic screening of carboxylic groups by sodium ions in the buffer solution. Availability of various functional groups on EWA has resulted in adsorption of metals (Cu^{++}) and non-metals ($PO_4^{=}$).

Whey Protein-Based pH-Sensitive Hydrogels

S. Gunasekaran*, M.M. Ould Eleya, L. Xiao

Funding: Dairy Mgmt., Inc.

Two sets of heat-induced gels were prepared from whey protein concentrate (WPC) at constant concentration of 15% w/v, under various pH conditions (pH 5.1, 5.7, 6.2, 6.8, 7.2, 10.0), and under various protein concentrations (12, 15, 18%). Alginate-coated WPC gels were also prepared. The swelling behavior of these gels was studied at different pH's at constant temperature 37.5±0.5°C. The swelling of WPC hydrogels depended on pH and concentration. The equilibrium swelling ratio (SR) reached minimum when the swelling medium pH was close to pI. When swelling medium pH was far away from pI (from 6.0 to 10.0), SR increased, especially when pH was higher than pI the swelling was highly pH-sensitive. Higher concentration led to lower SR. The SR of WPC hydrogel decreased significantly when surface-coated with alginate. Controlled drug release properties of the gels were studied under different pHs using caffeine as the model drug. The release was slower at lower medium pH (1.8) than at higher pH (7.5), consistent with their swelling behavior. The drug release was lowered by the alginate coating.

Large Deformation Rheology of Soluble Leaf Protein Gels

S. Gunasekaran*, R.G. Koegel, B.P. Lamsal

Funding: USDA Dairy Forage Research Ctr.

Soluble leaf protein (SLP) gels at different concentrations were prepared in molds by heating the protein solutions at 90°C for 60 minutes. Large strain deformation properties of 7.1% SLP gels, 11% and 13.2% whey protein isolate (WPI) gels, and 7.1% SLP/11% WPI mixed gels at 1:3 ratios at different salt strengths and neutral pH were evaluated with an MTS material testing unit. Uniaxial compression tests confirmed the weak gel properties of these gels. Addition of NaCl salt did not improve the SPL gel strength. SLP/WPI mixed gels showed synergistic effect only at the ratio of 1:3 of 1.9% SLP and 11% WPI solutions. Increasing ionic strength by adding NaCl had adverse effect on SLP/WPI mixed gels strength, though it was helpful with WPI gels near neutral pH values; so did raising pH values to 8.5 prior to gelation. Viscoelastic properties of the pure and mixed gels were also evaluated with stress relaxation tests up to 30% strain at different crosshead speeds. The SLP gels had highest stress decay rate, followed by SLP/WPI mixed gels at 1:3 ratios, and WPI gels. This was thought mostly due to coarser gel network and rapid release of hydrostatic pressure in SLP and mixed gels. While the applied strain levels at a given compression rate affected the initial stresses undergone by the samples, they did not affect stress decay rates. However, the initial compression rate did affect stress decay rates.

Performance Evaluation of Different Model Mixers by Numerical Simulation

S. Gunasekaran*, C. Yu

Funding: Hatch

The mixing performance of four types of mixers were investigated for Newtonian and shear-thinning fluids using numerical simulation. The blade designs of the mixers were: 1) rectangular blade, 2) single Z-blade, 3) two Z-blades, 4) three rotating cylinders. Finite element method was used for numerical solutions. Velocity distributions in the mixing chamber were computed with both 3D and 8- and 27-node brick elements. Pressure and stress distributions were also computed. Mixing effectiveness was evaluated by the flow number and volumetric strain rate. The flow number provided information about the type of flow in the system and volumetric strain rate about the overall mixing capability. These parameters were also computed.

Machinery and Harvesting

Engineering Aspects of Harvesting and Storing Corn Stover as a Biomass Feedstock

K.J. Shinners*, P.J. Wiemer, J.G. Coors

Funding: USDA Agric. Research Service; Wis. Corn Promotion Board; John Deere Technol. Ctr.

Cooperators: UW Biological Systems Engring.; USDA Dairy Forage Research Ctr.; UW Agronomy

This research deals with the engineering aspects of biomass feedstock production from corn crop residues. Biomass feedstock can be used to produce ethanol fuel by enzymatic hydrolysis of cellulose, to produce energy gasification or direct combustion at power plants, or to produce paper pulp. The objectives of this project were to determine: (1) yield and moisture of important corn plant fractions (grain, leaf, cob, husk, stalk) during senescence and prior to harvest, (2) drying rate of stover after harvest as affected by various physical treatments and time of harvest, (3) productivity and viability of harvesting wet stover compared to traditional dry harvest methods, and (4) storage losses of wet and dry stover. When grain moisture was between 30 and 20%, the ratio of stover to total dry mass was 43%. At harvest, 16, 8, 16 and 60% of the total stover dry mass resided in the cob, husk, leaf and stalk fractions, respectively. Stover moisture was between 65 and 58% during a typical grain harvest period. The leaf, cob and husk fractions dried considerably prior to grain harvest, but the stalk remained more than 65% moisture until grain harvest. Mechanically conditioning stover by shredding after grain harvest significantly improved the stover drying rate if the material was placed back on the surface in a swath about as wide as the shredder width. Placing the shredded material in a narrow windrow immediately after shredding significantly reduced the drying rate. No matter the treatment, in the three weeks after grain harvest only during a brief period was the stover at acceptable moisture for dry baling. Harvesting efficiency, i.e., the ratio of stover mass actually harvested to mass in the field, averaged 53, 56 and 33%, respectively, for chopping, wet baling and dry baling. Harvesting wet stover as chopped material and ensiling in a plastic bag was successful. The large square baler produced greater harvesting rate (20.9 *vs*. 11.2 kg DM/ha), density (149 *vs*. 109 kg DM/m^3), and harvesting efficiency (63% *vs*. 50%) than the large round baler. DM loss of ensiled stover at 47% moisture was 10.9% of total DM after seven months of storage. The stover pH was 4.1, and the level of fermentation products was quite low. DM loss of tube wrapped bales at 40% moisture averaged 3.6% after seven months' storage. Stover pH was 5.1, and fermentation products were very low. DM loss averaged 5 and 15% for bales stored indoors and outdoors, respectively. Average DM loss for dry bales stored outdoors was 8.9, 13.3 and 23.4% for bales wrapped with net wrap, plastic twine and sisal twine, respectively. Independent of wrap type, average DM loss of bales stored outdoors was 18.0 and 12.0% for bales stored on the ground and on a well-drained surface, respectively.

Harvest Fractionation of Alfalfa

K.J. Shinners*

Funding: Oxbo Corp.

Cooperator: UW Biological Systems Engring.

Since crop cultivation began, grain crops have been harvested by fractionating high-value kernels from low-value stalk. Within the last 50 years, there have been attempts to fractionate forage crops, specifically alfalfa, into high-value leaf or protein fractions and low-value stem or fiber fractions. These processes are known as wet- and dry-fractionation, and their use has been limited by many economical and operational difficulties. A major difficulty is that if the leaf and stem fractions are harvested as one, downstream processing is needed to facilitate separation. This research deals with a mechanism that strips alfalfa leaves from stems at harvest, immediately yielding a high-value fraction that consists mainly of leaves. The leaves could be direct ensiled using a variety of techniques or further processed to yield other value-added products. The standing fraction could be cut, wilted and chopped as high fiber roughage for ruminant animals or could be allowed to stand and re-grow new leaves. A full-scale field-going harvester implementing a mechanism to strip harvest leaves was tested in 2003. Stripping removed up to 94% of total leaf mass, depending upon the aggressiveness of the stripping rotor configuration. New leaves did re-grow from the stripped stem, but yield was low. Direct ensiling of the leaf fraction was quite successful when formic acid was used as a preservative or if ground corn grain was used as a moisture-lowering amendment. The drying rate of the stripped and cut stem fraction was considerably faster than the drying rate of the whole plant. Further research will be conducted to improve the systems for direct ensiling of leaf fractions and to estimate the economic viability of alfalfa harvest fraction.

Krusenbaum Dairy Farm Study

J.L. Posner*, R.T. Schuler and G.G. Frank

Funding: UW Agronomy; UW Biological Systems Engring.

Cooperators: UW Agronomy; UW Biological Systems Engring.; UW Ctr. for Dairy Profitability

Since 1990 scientists have followed changes and decision-making during the transition from a confinement dairy to a rotational grazing dairy and to organic milk production. Field machinery use and cost is being tracked on the Krusenbaum Dairy Farm near East Troy, Wisconsin. Machinery inventory has been significantly reduced since the transition began. But machinery cost has not been significantly reduced because initially tractors and tillage machinery were purchased as used. Later, forage equipment was purchased as new. The time associated with machinery operation has been substantially reduced.

Factors Affecting Bunker Silo Densities

R.E. Muck*, B.J. Holmes and P. Savoie

Funding: USDA Agric. Research Service; UW Biological Systems Engring.; Agric. and Agri-Food Canada

Cooperators: USDA Dairy Forage Research Ctr.; UW Biological Systems Engring.; Agric. and Agri-Food Canada

Objectives

This work is being conducted to identify factors which contribute to silage density in bunker silos. Knowing these factors will help producers understand what practices they must perform to achieve high density in their bunker and stored silage. Attaining high densities in silos is important for two primary reasons.

1. High densities reduce spoilage that occurs during storage and feedout.
2. The higher the density, the greater the silo's capacity.

Higher densities usually reduce annual storage costs per ton by increasing the amount of crop entering a silo and decreasing storage losses. Our objective was to determine which forage conditions and packing practices result in high density forage.

A forage packing simulation tower was constructed in the machinery lab of the USDA Dairy Forage Research Center. The tower is a 3-sided steel box that stands about 8 feet tall. Plexiglass panels are bolted onto the open front to enclose the forage in the box. Weighed quantities of forage are placed into the enclosed box to simulate forage layers placed into a bunker silo. A hydraulic cylinder forces a steel plate down onto the forage, simulating the packing process. The depth of the forage layer is measured before and after compression. Factors that have been assessed include: forage type (alfalfa, grass, whole plant corn), moisture content, layer thickness, packing force, frequency of applying force, force duration, and total depth of forage.

For all crops, density increased logarithmically as more layers were added. For whole plant corn, the most important factors affecting density were pressure, layer thickness, and kernel processing. Time of compaction within the range studied had a small effect on density, and moisture content did not affect it. For alfalfa and grass, pressure, moisture content, forage species and chop length affected density. Layer thickness and compaction time were less important.

Pressed Bag Silo Densities and Losses

R.E. Muck* and B.J. Holmes

Funding: Crop Storage Inst.; USDA Agric. Research Service

Cooperators: USDA Dairy Forage Research Ctr.; UW Agric. Research Stations

Our objectives for this work are to answer two questions.

1. How much forage is stored in a silo bag?
2. What are the dry matter losses of forage stored in silo bags?

Pressed bag silos are becoming increasingly popular with livestock producers because they offer a relatively inexpensive means of making silage and provide more flexibility in silage management than traditional tower or bunker silos. However, little is known about forage density and losses in bag silos. This study, initiated in 2000, intends to obtain estimates of both losses and density under good management and possibly the factors influencing variations in density and losses across bags.

The filling of 25 bags in 2000 and 22 bags in 2001 was monitored at three UW Agricultural Research Station farms (Prairie du Sac, Arlington, West Madison). The weights of all loads added to bags were recorded. Samples were taken of each load for moisture, ash and quality analyses, and particle size. The length of bag filled by each load was marked on the bag to obtain within bag variation in density by load. The major crops ensiled were alfalfa and whole plant corn. The weights of both good and spoiled silage being removed from bags are being recorded, and samples are being taken periodically for moisture, ash, and quality analyses.

Over the two years, the range of moisture content at ensiling was 41-71% wet basis, with alfalfa silage averaging 57% and corn silage averaging 63%. Dry matter (DM) densities ranged from 9.8 to 17.7 lbs/ft^3. Alfalfa averaged 13.2 lbs DM/ft^3 and corn silage averaged 12.2 lbs DM/ft^3. The data have not yet been thoroughly analyzed for the factors influencing density. However, at all three farms and across crops, DM density decreased linearly with increasing moisture concentration except in corn silage with one bagger where density was constant. Kernel processing seemed to reduce density in corn silage. The bagging machine, operator, and crop also affected average DM densities. Density within bags was highly variable. Densities at top and sides were approximately 40% of those at a bag's bottom center.

Losses from a bag are determined after it is emptied. Preliminary loss results for the 24 emptied bags are tabulated below.

Type of Loss	Range	Average	Average Minus Worst 6 Bags
Invisible plus uncollected	-0.3 to 22.8	9.5	8.7
Spoilage*	0.0 to 25.4	6.9	2.7
Total	-0.3 to 39.9	16.4	11.4

*Spoilage loss is that silage rejected by the cattle feeder.

Measurements of DM losses from the 24 bag silos made in 2000 have been completed, and losses were highly variable (0-40%). However, except for 6 bags with considerable spoilage loss (>15%), total losses averaged 11%. In one case, losses were attributed to bird damage on the top of the bag that was not noticed immediately. In another, the bag split open. Significant spoilage losses in other bags were essentially confined to crops ensiled at less than 60% moisture. Spoilage was also worse in bags fed out in summer. Half the bags had no spoiled silage or just minor amounts at the ends. Invisible and uncollected losses were higher at high moisture contents and when feed out rates were low (8 in/d). While more research is needed to study bagging machines with different systems of filling, the current study suggests that pressed bag silos can do an excellent job of preserving a crop provided:

1. Crops are ensiled between 60 and 70% moisture,
2. The bagging machine is set up properly to obtain a smooth bag of high density,
3. Feed out rates are a minimum of 1-2 ft/d, and
4. The farmer routinely monitors for and repairs punctures in the bags.

Intensive Forage Conditioning Systems

K.J. Shinners*

Funding: John Deere Ottumwa Works; John Deere Werke Zweibruken
Cooperator: UW Biological Systems Engring.

Forage producers in humid climates continue to struggle with crop damage from rainfall because the crop dries too slowly to be harvested at optimum moisture. Several new systems for more intensive forage conditioning have been introduced recently which intensively condition the stem because the roll set operates at near zero clearance. Our research has shown that conventional rolls, set up correctly with proper roll clearance, can almost achieve the drying rate of "intensive conditioners". Intensive conditioners improved forage drying rate to baling moisture by roughly 2-3 h compared to well set up conventional conditioners. After conditioning level, the most important environmental factor that affects forage drying is the amount of sunlight the crop is exposed to, a function of the swath width and solar insulation. Current research is focused on systems to modify the windrow structure at time of cutting to improve drying rate. Tedding at time of cutting was the most effective treatment to improve drying, followed by tedding the next day and then fluffing the windrow after cutting. Equipment is being developed to merge the cutting, conditioning, and tedding processes into a single machine so that the greatest benefit from intensive conditioning and full-swath drying can be realized without additional field operations.

Crop Response to Highly Productive Forage Systems

K.J. Shinners*

Funding: Kondex Corp.; John Deere Ottumwa Works
Cooperators: UW Biological Systems Engring.

Forage producers are quickly adopting more productive forage cutting and merging systems. For instance, the disk cutterbar mower-conditioner is becoming the prevalent means to cut forage crops. However, some producers are reluctant to adopt this technology because of concerns about crop damage from impact cutting and perceptions that the use of disk cutterbar mower-conditioners increases the ash content of the animal feed. Our research has shown that in fields where varmint infestations were low, the ash content of alfalfa cut with either cutting system is similar, 8.6 and 8.8% of total dry matter (DM) for sickle and disk cutterbars, respectively. In areas where varmint infestations were significant (e.g., gopher mounds), the ash content was significantly higher with the disk cutterbar (14.6% of DM) compared to the sickle cutterbar (12.8%). Forage producers with large forage harvesters are looking to new equipment to merge multiple windrows to meet the capacity of their harvesters. Mergers, which translate the crop onto adjacent windrows without dragging it along the ground, are becoming more popular. Our preliminary research has shown that mergers and rotary rakes produce similar ash content compared to the unmerged control treatment (~8.5% of total DM). Wheel rakes had significantly higher ash content at 9.7%.

Mapping Soil and Field Characteristics to Understand Soybean Yield

R.T. Schuler*, R.P. Wolkowski, C.R. Grau, A.E. MacGuidwan

Funding: Wis. Soybean Marketing Board; North Central Soybean Board
Cooperators: UW Biological Systems Engring.; UW Agronomy; UW Soil Sci.; UW Plant Pathology; UW Environmental Remote Sensing Ctr.; U. of Missouri; U. of Illinois; Iowa State U.; Michigan State U.; South Dakota State U.

Understanding soybean growth and yield variability in production fields by mapping soil and field characteristics is the primary goal of this six-state project Each state has two production fields involved in this study. The specific objectives include:

- Derive relationships of soil and field characteristics to soybean growth and yield;
- Establish guidelines for using soil and field characteristics and measurements as an aid for soybean production systems;
- Implement activities to improve coordination of research on mapping soil and field characteristics and the relationship of these characteristics to soybean yield.

Four fields in corn and soybean production located north of Madison in Dane County, 40-60 acres each, were identified for intensive geo-referenced data collection. Soil samples were collected on 1-acre grids and analyzed for P, K, pH, and soybean cyst nematodes. Data on plant stand, plant height, and weed stand were collected during the growing season. Remotely-sensed aerial data from satellite (three dates) and aircraft (one date) were collected late during the growing season. A handheld radiometer was also used to collect additional remotely-sensed data. Fields were scouted for pests and other anomalies such as equipment malfunctions, operator errors, and soil compaction.

Results of the 1-acre grid soil sampling indicate these fields have no cyst nematode problems, and nutrient levels and organic matter vary across them. Some of this geospatial variability was similar to the soybean yield variability. Preliminary analysis of the remotely-sensed data indicates similar patterns.

Similar data are being collected in the five other states on two fields each. In addition, University of Missouri researchers collected soil data on two fields using automated sensors for soil and field characteristics such as soil conductivity, topography, and electromagnetic properties. An order one soil survey was conducted on the same two fields. Researchers at the University of Illinois are focusing on the data analysis, and Iowa State researchers are refining a soybean growth model.

In Wisconsin data, field observations indicate equipment malfunction such as planter and sprayer skips and wheel traffic impact due to late pesticide application. Affected areas were mapped. White mold infestations were rated and mapped in the soybean field. Equipment malfunctions and operation and white mold infestations were observable in the remote sensing and yield data. Yield had a high degree of correlation with white mold infestation and topography.

Using Remotely-Sensed Data to Diagnose Soybean Yield Limiting Factors

R.T. Schuler*, R.P. Wolkowski, A.E. MacGuidwan and C.R. Grau

Funding: Wis. Soybean Marketing Board; North Central Soybean Board

Cooperators: UW Biological Systems Engring.; UW Soil Sci.; U. of Missouri; U. of Illinois; Iowa State U.; Michigan State U.; South Dakota State U.; UW Environmental Remote Sensing Ctr.

The focus of this six-state project is managing crop production using remote sensing to identify problems in production fields. Specific objectives of this study are:

- Determine the relationships between remotely-sensed data and biotic factors;
- Apply the developed relationships to field scale remotely-sensed data for mapping patterns of crop stress;
- Integrate remotely-sensed data with soil and field characteristics to predict potential yield limiting factors;
- Provide suggested procedures for use of remotely-sensed data as an aid to soybean production decisions.

Six model systems were established, with each of the six states being involved in three to five systems. Each state project involved soil and field characteristics related to water stress. The remaining models were phytopthora seedling/root rot, soybean cyst nematode, herbicide injury, white mold, and insect damage. Wisconsin dealt with soybean cyst nematodes and white mold. In 2002, the soybean plots experienced no white mold problems, so this model was not evaluated.

Research plots were established in a production field on the David Farm near East Troy, Wisconsin. Researchers in the UW Plant Pathology Department evaluated interactions of fungicide seed treatment, herbicide, brown stem rot, and soybean cyst nematode. Another added feature of this set of plots was pH variation across the eight replicates from 6.0 to 8.2. Plot size was increased to 20×25 feet to provide improved evaluation of the remotely-sensed data having a spatial resolution of three feet. Eight soybean varieties were planted with different levels of resistance to soybean cyst nematode and brown stem rot. Remote sensing was done with a handheld radiometer several times during the growing season and once from low-flying aircraft. The aircraft was equipped with two sensors providing multispectral (3 wavelengths) and hyperspectral (120 wavelengths).

Interaction between soil pH and variety resistance was very apparent in the remotely-sensed data and yield data. Also, some varieties had distinctive remotely-sensed data characteristics. Based on visual observations of the remotely-sensed data, some varieties could be identified easily in each replicate that often had no relation to yield.

Integration of Hay and Forage Equipment into Site-Specific Farming Systems

K.J. Shinners*

Funding: John Deere Ottumwa Works; John Deere Werke Zweibruken

Cooperators: UW Biological Systems Engring.

The focus of this research has shifted to technologies to provide real-time management information to forage producers and, more specifically, toward accurately sensing moisture on-the-go. In 2003, conductance, capacitance, and microwave sensor technologies were evaluated to measure the moisture of dry hay. Conductance, capacitance, microwave, and NIR sensor technologies were evaluated to measure the moisture of silage crops. The microwave sensor was the most accurate of those tested with dry hay because it was essentially density independent, although accuracy declined at higher moistures. This sensor was able to predict bale moisture within ±1 percentage unit 85% of the time. Conductance and capacitance sensors were highly dependent upon sensor presentation to the material, bale density and ambient temperature, which led to low accuracy. Correcting for these many variables would make calibration unacceptably expensive. Of the sensor technologies evaluated for silage crops, only the NIR sensor looks promising. This sensor was able to predict silage crop moisture within ±2 percentage unit 94% of the time in a controlled laboratory setting. This level of accuracy has not been verified under real-time field conditions. Future research with NIR sensors will focus on work to improve its accuracy on the forage harvester, to make it robust enough to handle field conditions, and to make it cost-effective.

EXTENSION

Electric Power and Energy Systems

Energy Conservation and Renewable Energy Education

P.W. Walsh*, S.D. Brachman, S.G. Gruder

Funding: Wis. Energy Conservation Corp., Milwaukee Sch. of Engineering

Cooperators: UW Coop. Ext.; Wis. Focus on Energy; UW Coop. Ext. Solid and Hazardous Waste Education Ctr.; Wis. Renewable Energy Network

The Wisconsin Focus on Energy program promotes adoption of energy conservation and renewable energy technology by Wisconsin's citizens, businesses, and governments. In collaboration with public and private sector partners, this program works through UW-Extension offices to deliver energy education to Extension's state-wide clientele regarding adoption of improved energy management techniques, technologies to save and generate energy, and incentives available through Wisconsin Focus on Energy (website www.focusonenergy.com) to stimulate adoption of energy conservation and renewable energy technology.

Machinery and Harvesting

Agricultural Field Machinery

R.T. Schuler*, K.J. Shinners and J.W. Nelson

Funding: UW Coop. Ext. Service; Wis. Farm Technol. Days, Inc.

Cooperators: UW Biological Systems Engring.; UW Soil Sci.; UW Agronomy; UW Dairy Sci.; various county Extension agents

Proper operation, maintenance and selection of agricultural field machinery is the primary focus of the agricultural machinery program. Specific machines and systems receiving the most attention in 2003 were mower-conditioners, forage harvesters, balers, planters, grain drills, and conservation tillage equipment.

Forage harvesting remains the primary interest of Wisconsin forage producers. New cutting and conditioning technology (specifically intensive conditioners, impeller conditioners, and disk cutterbars) continues to generate questions on its merits. Large square bales are growing in use because of very high productivity. However, these bales must be baled at lower moisture for proper storage due to their greater density compared to small rectangular bales. Producers have raised many questions on ways to reduce storage losses in large square bales.

In some areas of Wisconsin, soil conditions in fall 2002 were wet during harvest, resulting in field operations leading to potentially excessive soil compaction. Many crop producers recognize the potential for yield loss from compaction and had questions about determining the extent of the problem in their fields and about alleviating the detrimental effects of excessive compaction. Various tillage practices were recommended as a means of reducing the effects of compaction on crop yield.

Wisconsin's annual Farm Technology Days (FTD) provides opportunities to work with the farm machinery industry to demonstrate field machinery and to reach thousands of farmers. Field demonstrations at FTD allow comparison of machines harvesting forage as chopped silage and bales. Other demonstrations were of mower-conditioners, rakes, and mergers. Forage samples were collected from the windrows to analyze the drying rate of material from mower-conditioner demonstrations. The primary factor influencing drying rate was windrow width. These results were displayed on display panels in the field.

Dairy Production

Dairy Modernization Programs

D.W. Kammel*

Cooperator: UW Coop. Ext. Service

Dairy modernization encompasses a variety of issues, farm decisions, and extension programming efforts. This includes programming and coordinating programs in dairy facilities and feeding systems including low-cost milking centers, freestall barns, special needs and transition cow barns, and TMR feeding equipment. Much of this work has been with family dairy farms in transition from 60 to 80 cows in a tie stall barn to a parlor freestall system. Stepwise and planned growth is more easily acccomplished and managed by farm owners who are struggling with changing and adapting newer and more labor-efficient technology to their dairy system. This work has been accomplished through the Dairy Modernization workgroup of the UW Cooperative Extension Service Dairy Team which I co-chair and the four-state extension effort. Proposals were developed to request funds to support work on several fronts in dairy modernization including website development, a dairy construction cost database, and survey and evaluation work coordinated through the Dairy Team. Funding for these proposals is expected in 2004.

Dairy Production and Profitability

B.J. Holmes*, D.R. Reinemann, D.W. Kammel, K.G. Josefsson

Funding: UW Coop. Ext. Service

Cooperators: UW Biological Systems Engring.; UW Healthy Farmers, Healthy Profits Project; UW Dairy Sci.; UW Ctr. for Dairy Profitability; U. of Minnesota; U. of Illinois; Iowa State U.; MidWest Plan Service

Increasing profitability on dairy farms requires proper selection of facilities for housing, feeding, and milking. The following strategies have been proposed.

- Enhance milk production efficiency by improving cattle environment including long day lighting which has the benefit of improving the safety of producers while working in the barn.
- Reduce electric hazards by improving efficiency of electrical energy use.
- Increase milk harvesting profitability by properly selecting milking equipment and facilities.

• Improve efficiency of feed storage and handling through better methods to provide balanced diets and adequate feeding space.
• Enhance dairy industry modernization by encouraging selection of profitable facilities.
• Protect water quality through improved methods of handling and storing manure and milking center wastewater.

In collaboration with companies, other universities and other UW departments, faculty have planned and participated in conferences on a variety of dairy-related topics. We have developed publications and software to inform farmers and their advisors on farmstead planning, feed storage, feeding, milking, animal housing, and manure handling systems.

Faculty have aligned themselves with self-directed teams such as the UW Cooperative Extension's Dairy Team and the Four-State Dairy Programming effort. Faculty have assumed leadership roles within the Dairy Team. Extension educational programs related to dairy will be coordinated within a team.

The Dairy Modernization workgroup of the UW Cooperative Extension Service Dairy Team developed and is marketing a collection of materials on a CD (*Milking Parlor Start-up*, *Low Cost Parlor and Dairy Housing and Manure Management Alternatives*) for use by agents, instructors at vocational/technical schools, and farmers to help with decision-making when transitioning from stall barn milking to milking in a remodeled parlor and housing cows in freestall barns.

Maintaining Forage Quality from Harvest through Storage and Feeding

B.J. Holmes*, R.T. Schuler, K.J. Shinners, R.E. Muck, K.G. Josefsson

Funding: UW Coop. Ext. Service; UW Biological Systems Engring.; USDA Dairy Forage Research Ctr.

Cooperators: UW Coop. Ext. Service Team Forage; UW Agronomy; UW Healthy Farmers, Healthy Profits Project

Forage is an extremely valuable component of the feed for dairy and beef animals. The quality of forage as delivered has a significant impact on the production efficiency of these animals. However, losses in feed quantity and quality through harvest, storage, and feeding are very high on many dairy and livestock farms. The following practices contribute to these losses.

• Hay exposed to precipitation.
• Hay harvested too moist.
• Hay stored without adequate protection from precipitation.
• Hay and corn silage harvested too dry or too wet.
• Haylage and corn silage inadequately packed and/or covered in bunker silos, piles, and silo bags.
• Haylage and corn silage improperly removed from bunker silos, piles, and silo bags.
• Corn silage improperly processed.
• Improper use of inoculants and additives which are used to enhance forage fermentation and preservation.

Presentations have been made at Wisconsin Forage Council meetings, Forage Field Days, and county extension meetings to encourage producers to improve management in these areas. Articles on these subjects have appeared in the *Minnesota/Wisconsin Engineering Notes* newsletter, in conference proceedings, and on the UW Extension's Team Forage website http://www.uwex.edu/ces/crops/uwforage.htm. Spreadsheet software was developed as a decision aid and is also at this website.

Forage production members of Team Forage have encouraged producers to select appropriate varieties, to properly adjust equipment, and to harvest at the correct stage of maturity to enhance yield and quality. Our group has been working to preserve and feed as much of that yield and quality as possible. As such practices are adopted, the efficiency of forage production and livestock feeding will improve. The Harvest and Storage Work Group of Team Forage has established a website, http://www.uwex.edu/ces/crops/uwforage/storage.htm to provide access to publications and software related to these topics.

Milking Technology and Facilities

D.J. Reinemann*, P.L. Ruegg, N. Cook, K.V. Nordlund

Cooperators: UW Biological Systems Engring.; UW Dairy Sci.; UW Sch. of Veterinary Medicine

Use of automated milking parlors is rapidly increasing in Wisconsin, and robotic milking machines have been introduced. Our program prepares agricultural professionals and dairy operators to effectively transition from stanchion barn milking systems to automated milking parlors or robotic milking systems. Educational programs for University students, county Extension agents, and other agricultural professionals were developed. They were offered in the Milking Research and Instruction Lab of the Biological Systems Engineering Department in cooperation with UW Extension's Team Quality Milk led by Dr. Pamela Ruegg (UW Dairy Science) and Drs. Ken Nordlund and Nigel Cook (UW School of Veterinary Medicine). Other educational activities include presentations at county, state, and national meetings and seminars, the development of computer-assisted milking center design aids, and news releases.

Environmental Quality

Improving Water Quality

B.J. Holmes*, D.W. Kammel, J.O. Peterson, D.J. Reinemann

Funding: UW Coop. Ext. Service

Cooperators: UW Biological Systems Engring.; UW Environmental Resources Ctr.; UW Soil Sci.; UW Nutrient and Pest Mgmt.; UW Ctr. for Dairy Profitability; USDA Natural Resource Conservation Service; Wis. Dept. of Agric., Trade, and Consumer Protection

The collaborators developed a series of educational materials and seminars and participated in events to educate communities and agencies about water quality issues. The following topics are included.

X Proper storage and handling of fertilizers, pesticides, and fuel to minimize losses to water resources.

X Regulations and standards to store and handle manure aimed at reducing the amount of manure and nutrients entering surface and ground water.

X Demonstrations of equipment and management to practice conservation tillage techniques that have proven effective in reducing soil erosion.

X Self-assessment techniques (FarmXAXSyst program) to deter-mine farmstead practices posing high risks to surface and ground water quality.

X A survey of grazier outwintering practices that could affect surface runoff of nutrients.

X Development of an environmental management system (EMS) for dairy farms to reduce environmental risk and increase envi-ronmental protection.

X Development of a standard for designing systems to manage milking center wastewater.

X Investigation of environmentally friendly cleaning and sanitizing agents.

X Demonstration of ground water flow and contaminant transport using sand tank models.

Wisconsin is one of three pilot states selected to develop and test EMS's for dairy farms, and efforts are underway to do so. (See "Wisconsin Pilot of Dairy Environmental Management Systems" above, p. 8.) Some materials we developed in previous years have been used as the basis of this EMS project.

Domestic On-Site Wastewater Management

J.O. Peterson*, J.C. Converse, E.J. Tyler

Funding: UW Coop. Ext. Service

Cooperators: UW Biological Systems Engring.; UW Environmental Resources Ctr.; UW Soil Sci.; Wis. Dept. of Commerce

Unsewered areas of Wisconsin depend upon septic systems for wastewater disposal. The Small Scale Waste Management Project develops and improves siting, designing, installing, and operating criteria for safe use of on-site treatment and disposal systems. Extension programs bring UW research results and applications to site evaluators, installers, designers, regulators, maintainers, and the general public.

Winter, spring and fall workshops are held annually at four or five sites on topics including:

X Soil properties and description;

X Soil treatment and dispersal systems;

X Evaluation and maintenance of on-site systems;

X Design of distribution systems;

X Pre-treatment systems;

X Design of mound and at-grade soil dispersal systems.

As information becomes available and needs are identified, topics are added and agendas are revised. Educational presentations are made at the Annual Winter Meeting of the Wisconsin On Site Waste Recycling Association and national organizations. These presentations include reviews and updates on research from the Small Scale Waste Management Project, an exploration of research needs, and extensive interaction on progress being made nationally.

Field sessions on soil properties and system operation and maintenance are scheduled as needed.

Safety and Health

AgrAbility of Wisconsin

R.T. Schuler*, S.L. Hicken, C.A. Skjolaas

Funding: USDA CSREES; UW Coop. Ext. Service

Cooperators: UW Biological Systems Engring.; Easter Seals Wis.; Wis. Div. of Vocational Rehabilitation

This partnership of the UW Cooperative Extension Service and the FARM Center of Easter Seals Wisconsin (ESW) provides education and assistance to farmers with disabilities and to disabled members of their families. Extension staff provides education and awareness of AgrAbility through extension/outreach activities. ESW's role is to give on-farm help via worksite assessments and development of individual plans.

During its 12 years, AgrAbility of Wisconsin has provided direct assistance to about 1100 disabled farmers and disabled members of their families. Disabilities addressed include cancer, lower back pain, spinal cord injuries, amputations, respiratory and cardiac problems, and visual and hearing impairments.

A close relationship has developed with the Wisconsin Division of Vocational Rehabilitation (DVR) which provides on-site support to farmers to implement their assistive technology plans and to refer them to the AgrAbility program. Examples of assistance provided are computer software, air-suspension tractor seats, added tractor steps, powered feed carts, milking pipelines, personal transport machines, and tractor lifts. DVR counselors have received training from AgrAbility staff regarding accommodations most effective for farmers with disabilities.

Awareness of this program is created through staffed displays at machinery shows and demonstrations and presentations at county, area, and statewide events. A quarterly newsletter is prepared and sent to county Extension offices, DVR offices, rural hospitals, and current and former clients. Staff personnel continue an in-depth awareness program through radio programs, newspaper articles, and visits to key community people and events. An advisory committee meets annually and provides excellent support and increased awareness.

National AgrAbility Project

R.T. Schuler*, C.A. Skjolaas, M.E. Novak, R.H. Meyer, M.F. Beck, S.D. Grunder, T. Willkomm

Funding: USDA CSREES; UW Coop. Ext. Service

Cooperators: UW Biological Systems Engring.; Natl. Easter Seals

The National AgrAbility Project provides training and educational support for the 24 state AgrAbility projects. These projects provide education and assistance to disabled farmers as described above for AgrAbility of Wisconsin. The national project requires a joint effort between state Cooperative Extension staff and staff from a non-profit disability organization, which is National Easter Seals. Training and education are provided through a national workshop, monthly newsletters, quarterly technical news, and e-mail. The website www.agrability-project.org was developed and will be further refined to provide

information to state project staff and the general public. The website provides access to an assistive technology database listing more than 1000 items. A photo library recently became available to staff of state projects. The monthly newsletter is distributed electronically only. A National Workshop was planned and held in Omaha to provide training for state staff and others serving farmers with disabilities.

Evaluation of all aspects of the project is a major component and has been initiated. A needs assessment for the state projects was developed and implemented. Plans have begun to determine how well the state projects are meeting the needs and expectations of the farmers whom they are serving. An impact survey has been developed that will indicate how well AgrAbiity is meeting the needs of farmers with disabilities.

Youth Agricultural Safety and Health

C.A. Skjolaas*, C.C. Wilke, M.A. Purschwitz, R.T. Schuler
Funding: UW Coop. Ext. Service
Cooperator: UW Biological Systems Engring.

Youth are at risk of serious and fatal farm injuries. Each year several Wisconsin children and youth, from preschool through high school age, die from farm work or worksite-related injuries. Youth must learn proper, safe behaviors in a farm environment, both to avoid hazards as bystanders and to work safely. Youth must also learn fundamental injury and illness prevention techniques, such as hazard control, and must be motivated to apply such techniques during their lifetimes.

This program includes presentations to youth at a variety of meetings, both in and out of a school setting. Presentations and planning assistance are provided to youth safety day camps throughout the state. Safety materials are being developed for Extension agents and, within 4-H and vocational agricultural programs, for children and youth. Close contact is maintained with county Extension agents who work with youth and agricultural education instructors. The tractor and machinery certification program described under the section "Youth Education" (below) is part of this overall youth safety and health programming.

Farm Machinery Systems Safety

M.A. Purschwitz*, R.T. Schuler, C.A. Skjolaas, C.C. Wilke
Funding: UW Coop. Ext. Service
Cooperator: UW Biological Systems Engring.

Farm tractors and other machines are involved in the majority of incidents resulting in fatal or permanent injury. The most effective method of preventing injuries involves hazard control (removing or guarding hazards). Safe, proper operation is still necessary but cannot be depended upon to completely prevent machine-related injuries. Numerous presentations, media interviews, and information requests on machinery safety are handled. We prepare an annual state farm fatality report which highlights machinery-related fatalities. Safety information is added to the Internet website for the UW Center for Agricultural Safety and Health. In-depth instruction on machine hazards and hazard control is a major component of the UW's Farm and Industry Short Course class, "Agricultural Safety and Health".

Youth Education

Mechanical Sciences (Youth Development)

R.T. Schuler*, C.A. Skjolaas, J.W. Nelson, M. Miller
Funding: UW Coop. Ext. Service; Wis. Rural Insurance
Cooperators: 4-H Youth Development; Natl. Engring., Sci. and Leadership Mgmt. Team; Lincoln Welding; Deere and Co.

Approximately 16,000 youth participate in these Mechanical Science projects at the county level. About 2000 county volunteers direct them. Biological Systems Engineering Department staff provides technical support for the 4-H mechanical science projects including woodworking, tractor, small engine, electricity, bicycle, and aerospace. Fifteen county agricultural and youth development Extension agents and county youth development volunteers supported state events. Winners at the state level go on to the National 4-H Engineering, Science, and Leadership Event held at Purdue University. Wisconsin staff is responsible for the small engine activity at the national event and is part of the management team that plans and conducts this event.

Future Farmers of America Agricultural Mechanics Events

R.T. Schuler*, J.W. Nelson, C.A. Skjolaas, S.L. Hicken
Funding: UW Coop. Ext. Service
Cooperators: UW Biological Systems Engring.; Wis. Future Farmers of America

In 2003, 23 teams took part in the Wisconsin FFA Agricultural Mechanics event. Each year the top teams from four area Agricultural Mechanics contests take part in a statewide event organized by Biological Systems Engineering staff. Guidelines are developed for the four area events. The state event also gets input from faculty at UW-River Falls, UW-Platteville, and the Fox Valley Technical College who direct area events. Biological Systems Engineering Department staff also help plan the national event and provide training for agricultural educators in Wisconsin.

Tractor and Machinery Operation Certification Program

C.A. Skjolaas*, C.C. Wilke, M.A. Purschwitz, R.T. Schuler
Funding: UW Coop. Ext. Service
Cooperator: UW Biological Systems Engring.

Federal child labor laws require specific training on tractor and machinery operation for youth ages 14 to 15 working on farms other than those of their parents. Wisconsin law requires such training for youth 12 to 16 years old who operate tractors or other farm machines on public roads. Training programs are conducted by county Extension agents working with youth and by agricultural education instructors with help from many volunteers. Greater standardization was brought into the program statewide and help was offered to counties that had not previously offered programs. Supplemental materials such as an instructor training manual were developed, and instructor training was offered statewide. These efforts have resulted in more than a thousand youth successfully completing certification programs annually.

AWARDS

Faculty and Staff

Gary D. Bubenzer. President's Citation from the American Society of Agricultural Engineers in recognition of his outstanding contributions to ASAE during the preceding year. Prof. Bubenzer served as Treasurer and Chair of the Finance Committee.

James C. Converse. President's Citation from the American Society of Agricultural Engineers in recognition of his outstanding contributions to ASAE during the preceding year. Prof. Converse was Director of the Meetings Council and Chair of the Meetings Committee.

James C. Converse. Special Recognition by the American Society of Agricultural Engineers to recognize his role in the On-Site Wastewater Treatment Workshop.

James C. Converse. Advising Award by the College of Agricultural and Life Sciences for undergraduate education.

Sundaram Gunasekaran. 2003 Research Award from the International Dairy Foods Association for developing the UW Profiler and UW Meltmeter and their related data analysis software to evaluate rheological properties of cheese. Based on principles of squeeze flow rheometry, they measure changes in physical properties (e.g., in taste and texture) when cheese is heated, as when pizza and other foods containing cheese are baked.

Brian J. Holmes. Special Recognition by the American Society of Agricultural Engineers to recognize his role in the National Dairy Housing Conference.

Jeffrey W. Nelson. J.S. Donald Short Course Teaching Award by the College of Agricultural and Life Sciences for outstanding support of the Farm and Industry Short Course Program. He teaches the Farm Power and the Farm Machinery courses.

Aicardo Roa-Espinosa and Biological Systems Engineering Dept. Certificate of Appreciation from the U.S. Marine Corps for developing a method of coating spaces used as helicopter landing sites with a biodegradable polymer coating that causes sand and dust particles to clump together, thus reducing equipment wear and failure and visibility problems associated with dust clouds stirred up by a helicopter's rotors.

Cheryl A. Skjolaas. Academic Staff Award for Leadership Excellence by the College of Agricultural and Life Sciences for developing innovative, creative materials on safety and health aimed at both youth and adults and for educational support to county Extension agents and agricultural education teachers and her leadership in AgrAbility of Wisconsin, the National AgrAbility Project, the UW Center for Agricultural Safety and Health, and the National Institute of Farm Safety.

Debra K. Sumwalt. SPA Frontline Award from the UW-Madison Student Personnel Association in recognition of her excellence in service as someone in a "frontline" position.

Students

Joshua D. Bacon and Benjamin N. Binversie (graduate students). Recognized as Outstanding Graduate Students in Biological Systems Engineering by the Wisconsin Section of ASAE for their research accomplishments and support of the department's Pre-professional Club, with key roles in the lawnmower/snowblower clinic and quarter-scale tractor team.

Julie L. Graham (undergraduate). Recognized as the Outstanding Undergraduate Student in Biological Systems Engineering by the Wisconsin Section of ASAE for her excellent academic record and activities in the department's Pre-professional Club and other campus clubs.

Jill A. Grodecki (undergraduate). Received a Steuben Award for Outstanding Engineering Students from UW's College of Engineering for her paper on anaerobic digestors ($3,000).

Jill A. Grodecki (undergraduate). Received a Student Honors Award from the American Society of Agricultural Engineers to recognize her academic achievements and leadership and participation in student activities.

Jill A. Grodecki (undergraduate). Received a Harvey Meyerhoff Undergraduate Excellence Award from the University of Wisconsin-Madison for academic achievement, leadership and service.

Karen M. Mandl (undergraduate). Received an Outstanding Senior Award by the College of Agricultural and Life Sciences in recognition of superior academic performance and involvement in extracurricular activities both on and off campus.

Quarter-scale Tractor Team. Placed seventh among 30 teams participating in the ASAE-sponsored competition. The team placed third for their written report, seventh in both oral presentation and static design evaluation, and eighth in the performance test (pulling). In their 2003 design, a 16-hp engine powered a generator that provided current to four electric motors, one at each wheel, for superior wheel control. If one wheel slipped while the tractor was under a tractive load, more power was directed to the other wheels.

Pre-professional Student Club. Placed first in the Group B Competition of the Association of Equipment Manufacturers for their accomplishments during the 2002-03 school year. The award is based on club activities such as club meetings, tours, participation in campus activities, and involvement in the International ASAE and the Wisconsin Section of ASAE.

PUBLICATIONS

PEER REVIEWED PUBLICATIONS

Alvarez-Blanco, S, SO Manolache, FS Denes. 2003. Synthesis of polyaniline using horseradish peroxidase immobilized on plasma-functionalized polyetheylene surfaces as initiator. *J Appl Polymer Sci* 88(2):369-379.

Ay, C, S Gunasekaran. 2003. Numerical method for determining ultrasonic wave diffusivity through coagulating milk gel system. *J Food Engring* 58(2):103-110.

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Bohnhoff, DR. 2003. Lateral movement of unbraced trusses during construction. *Wood Design Focus* 13(4):6-10.

Chapman, LJ, AC Newenhouse, RH Meyer, B Karsh, AD Taveira, MG Miquelon. 2003. Musculoskeletal discomfort, injuries, and tasks accomplished by children and adolescents in Wisconsin fresh market vegetable production. *J Agric Safety and Health* 9(2):91-105.

Chapman, LJ, AD Taveira, KG Josefsson, D Hard. 2003. Evaluation of an occupational injury intervention among Wisconsin dairy farmers. *J Agric Safety and Health* 9(3):197-209.

Chorover, J, S Choi, MK Amistadi, KG Karthikeyan, G Crosson, K Mueller. 2003. Linking cesium and strontium uptake to kaolinite weathering in simulated tank waste leachate. *Environmental Sci and Technol* 37:2200-2208.

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