Preface

In September, 2004, the Biological Systems Engineering Department celebrated its 100th anniversary. As the oldest agricultural engineering department in the United States, the department has been a national leader in research, teaching, and extension. We look forward to the next hundred years with anticipation. As the following summary shows, we are doing exciting things.

To that end, we are pleased to provide you with our 2005 Annual Summary, based on activities underway and completed in 2004. The Biological Systems Engineering Department is affiliated with the College of Agricultural and Life Sciences, the College of Engineering, the UW-Madison Agricultural Research Stations, and the University of Wisconsin Cooperative Extension Service. 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 pwwalsh@wisc.edu; telephone 608-262-3310; FAX 608-262-1228; or mail your comments to:

Biological Systems Engineering Department
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Patrick W. Walsh
Professor and Chair

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Faculty

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

Robin K. Connelly, Assistant Professor
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
Director, Center for Dairy Profitability

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

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, Ph.D.
Extension / Research / Teaching: power and machinery

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
Chair, UW Biological Systems Engineering Dept. and
Co-Chair, 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

Mark A. Purschwitz, Adjunct Associate Professor, Ph.D.
Research Scientist, National Farm Medicine Ctr. (in Marshfield, WI): agricultural safety and health

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
Gary D. Bubenzer
Frederick H. Buelow
Calvin O. Cramer
Marshall F. Finner
Richard G. Koegel
Leonard R. Massie

Academic Staff

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

AAW – 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.

Cally A. Abplanalp, Associate Outreach Specialist; AAW
LeahNell Adams, Outreach Specialist, M.S.; NAP
Mary F. Beck, Outreach Specialist, M.S.; NAP
Juliane M. Bowling, Research Intern, M.S. (K.G. Karthikeyan)
Larry J. Chapman, Senior Scientist, Ph.D.; HFHP
Luis E. Cruz-Barba, Research Associate, Ph.D. (F.S. Denes)
William E. Enters, Research Specialist; Environmental Quality Lab (J.C. Converse, K.G. Karthikeyan)
Joseph D. Grande, Research Specialist, M.S. (K.G. Karthikeyan)
Steven D. Grunder, Assoc. Outreach Specialist, M.S.; NAP
Andrew Hopfensperger, Distinguished Outreach Specialist; drafting and technical illustrating
K. Gunnar Josefsson, Assistant Scientist, M.S.; HFHP
Yonghui Ma, Research Associate, Ph.D. (F.S. Denes)
Soren Manolache, 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 (departmental IT) and Lecturer (farm equipment and power), M.S.
Astrid C. Newenhouse, Assistant Scientist, Ph.D.; HFHP
Mark E. Novak, Outreach Specialist; NAP
Kathryn Pereira, Assoc. Outreach Specialist, M.S.; HFHP
Mark E. Raabe, Research Specialist, M.S.; Midwest Rural Energy Council (D.J. Reinemann)
Daniel C. Rodman, Lecturer (surveying; also Dept. of Civil and Environmental Engineering), M.S. (P.W. Walsh)
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

Technical Personnel

Harold M. Bohne, Senior Instrument Maker
Bradley A. Brooks, Instrumentation Specialist

Office Personnel

JacqueLynn M. Cary-Pope, Financial Specialist
Hallie R. Kirschner, Program Assistant
Sherry T. Liantonio, Program Assistant
Candy L. Pharo, Department Administrator
Debra K. Sumwalt, Program Assistant

Graduate Students

Names of major advisor follow in parentheses

Graham S. Adsit (K.J. Shinners)
Filiz Altay (S. Gunasekaran)
Nathan Q. Altfeather (D.J. Reinemann, P.W. Walsh)
Shanti Bhushan (R.K. Connelly)
Benjamin N. Binversie (K.J. Shinners)
Perry E. Cabot (K.G. Karthikeyan)
Amanda D. Crowe (A.M. Thompson)
Matthew F. Digman (K.J. Shinners)
Baiyan Dong (F.S. Denes)
Philip D. Gaebler (K.G. Karthikeyan)
Joseph D. Grande (K.G. Karthikeyan)
Cheng Gu (K.G. Karthikeyan)
Kerem Gungor (K.G. Karthikeyan)
Jason M. Helgren (D.J. Reinemann)
Jennifer L. Hermans (D.J. Reinemann)
Matthew E. Herzmann (K.J. Shinners)
James B. Jordan (R.K. Connelly)
Sanghoon Ko (S. Gunasekaran)
Andrew J. Kotloski (B.J. Holmes, K.J. Shinners)
Seth B. McClure (K.G. Karthikeyan)
Rebekah L. McIntier (R.K. Connelly)
Gregory D. Mueller (A.M. Thompson)
Jane L. O'Dell (R.M. Rowell)
John C. Panuska (K.G. Karthikeyan)
Adam C. Paul (A.M. Thompson)
Adam L. Petersen (A.M. Thompson)
Ajay Singh (S. Gunasekaran)
Changhui Sun (S. Gunasekaran)
Sai Kit (Terry) Tau (S. Gunasekaran)
Jeffrey B. Topel (R.T. Schuler)
Vladimir Totolin (F.S. Denes)
Anthony J. Vandermuss (A.M. Thompson)
Hongwei Zhu (K.G. Karthikeyan)

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

Biological Systems Engineering

Currently there are about 60 undergraduate majors in Biological Systems 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
Operating and Management Principles of Agricultural Machines, 3 cr
Engineering Principles of Agricultural Machinery, 3 cr
Measurements and Instrumentation for Biological Systems, 3 cr
Food Engineering Operations, 4 cr
Food and Pharmaceutical Separations, 2-3 cr
Rheology of Foods and Biomaterials, 2 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
Topics in Renewable Energy Systems, 1-4
Biological Systems Engineering Senior Design, 3 cr
Career Management for Engineers, 1 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. Approximately 20 students earn B.S. degrees each year.

Service Courses

The department provides several 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
Operating and Management Principles of Off-Road Vehicles, 3 cr
Engineering Principles of Off-Road Vehicles, 3cr
Principles of Food Engineering, 3cr

Farm and Industry Short Course Program

The department teaches the following courses for the Farm and Industry Short Course (FISC) program offered through 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 about 30 graduate students are 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.

Characteristics and Educational Needs of Agri-Industry

D.R. Bohnhoff*, G.W. Williams, K.A. Rosentrater

Funding: UW Biological Systems Eng.; FWS Construction, Ltd.

An agri-industrial company is herein defined as any firm that is involved in the post-harvest storage and/or processing of agricultural and agricultural-based commodities. This may include port terminals, pet food processing plants, feed mills (general, bovine, fish, mink, swine, poultry, etc.), flour mills, grain handling and storage facilities, meat processing plants, canning factories, bottling plants (milk, soda, fruit juice, etc.), malting plants, breweries, sawmills, paper mills, ethanol and other biomass plants, textile mills, seed processing facilities, bakeries, confectionaries, cheese factories, and thousands of other food and bioprocessing facilities.

Despite our tremendous reliance on agri-industry, colleges and universities in North America have very little programming dedicated specifically to agri-industry, even though agri-industry has measurable needs – needs that become more critical with advancing technologies and expanding government regulations. It seems logical that agricultural and biological engineering departments at North American universities would step forward to meet these needs. Unfortunately this has not occurred to a great extent. One reason for this is that many departments are simply not as familiar as they should be with agri-industry characteristics and educational needs. In recognition of this, we set out to define the industry, its characteristics, and its educational needs.

The results of our agri-industry research culminated in four technical papers presented at the 2004 ASAE/CSAE International Meeting in Ottawa, Ontario. The first of these papers defines North American agri-industry. Specifically, it uses the North American Industry Classification System and the definition of agri-industry to identify major industry segments. These include food, beverage and tobacco manufacturing, wood, leather and fiber processing, and wholesaling and storage of non-durable goods. This paper contains numerous maps identifying regions of production and discusses current Gross Domestic Product and projected industry growth.

The second paper was written to familiarize students and educators with engineering job titles and associated responsibilities, as well as working relationships between planners, owners, and builders as they relate to agri-industry facility planning, construction, and operation. Job responsibilities were presented for eleven facility planning and construction positions and six facility operation positions. Planning and construction position titles included: civil engineer, geotechnical engineer, architectural engineer, structural engineer, HVAC engineer, plumbing engineer, environmental engineer, electrical engineer, instrumentation and control engineer, process engineer, and construction engineer. The six position titles defined for facility operation were: maintenance engineer, operations engineer, quality control engineer, environmental health and safety engineer, process electrical engineer, and product/process development engineer. Titles used to designate engineering rank were presented, as well as definitions for position titles of design engineer, project engineer, plant engineer, production manager, facility manager, and plant manager. The role of owners, architectural/engineer firms, design-build firms, and construction contractors in facility planning and construction were overviewed. Examples demonstrating the need for integration and simultaneous design of building, HVAC, and processing systems were given. The advantages of using design-build firms for agri-industry facility development were presented.

The third paper summarizes educational needs for agri-industrial facility designers and managers. Relevant skills required for the design, planning, and operation of agri-industrial facilities are discussed. Continuing and University educational needs for facility designers and managers are also presented.

The last of the four papers outlines modifications that this Biological Systems Engineering (BSE) Department faculty have considered and are considering for the undergraduate engineering curriculum – changes that will result in graduates who are better prepared for careers as agri-industrial facility designers. The proposed changes include four new courses: "Agri-Industrial Facility Design," "Process Systems Design," "Renewable Energy Technologies," and "Sustainable Residential Construction." These new courses would be a major part of a novel program option with a proposed title of Facility Design, Construction, and Management. It is hoped that these new courses, as well as other proposed curriculum changes, will result in more commonality among all BSE program options and, consequently, will unite and strengthen the overall BSE program. These progressive steps, in fact, could serve as a model for other departments throughout the country.

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 Eng.; 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 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 aerobic treatment units (ATUs), two attached growth ATUs, single pass sand filter, and recirculating sand filters (RSFs) 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 RSFs 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.

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 Eng.

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.

Biosensor Development

D.J. Reinemann*, F.S. Denes, J.M. Helgren

Funding: H.D. Bruhn Fellowship
Cooperator: UW Biological Systems Eng.

The objectives of this project are to:

- 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.

Wisconsin Bio-Refining Development Project

D.J. Reinemann*, P.W. Walsh

Cooperators: The Energy Ctr. of Wis.; Wis. Dept. of Administration; US Dept. of Energy Industries of the Future

The purpose of this project is to facilitate a coordinated effort to expand bio-refining in Wisconsin by emphasizing that bio-refining provides viable commercial opportunities today. The two primary tasks are:

1. Compile a "roadmap" of information on bio-refining that industry needs to understand the opportunities, barriers, and resources for refining multiple products from biomass feedstocks and residuals so industry can start pursuing bio-refining projects;
2. Disseminate this roadmap information and initiate follow-up actions through a video-based workshop approach.

The Bio-Refining Roadmap website (www.wisbiorefine.org/index.html) was launched in conjunction with the video workshop in June of 2004.

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 Eng.; UW Dairy Sci.

The objectives of this research effort are:

- Assess milk quality of robotic milking systems in the U.S.;
- Evaluate the economic viability of robotic milking technology;
- Identify the key management factors necessary 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 2003, supported by the data collected in this study. The NCIMS voted to approve, and the FDA concurred in September 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.

Development of Field Tests of Milking Performance

D.J. Reinemann*, P.L. Ruegg, G.A. Mein, M.D. Rasmussen

Cooperators: UW Biological Systems Eng.; UW Dairy Sci.; UW Sch. of Veterinary Med.; Danish Inst. of Agric. Sciences

This international team of researchers is assembling a bulletin for publication by the International Dairy Federation to provide 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.

Investigation of UV Treatment of Milk and Milk Products

D.J. Reinemann*, J.R. Bishop, K.B. Houck

Funding: Pure UV

Cooperators: UW Dairy Sci.; UW Ctr. for Dairy Research

A novel UV light treatment system is being evaluated for sanitizing milk and milk products. The objectives of this study are to establish the effect of UV treatment on the total psychrotrophic, themoduric, and spore-forming bacteria load of raw farm milk and the collateral effects of UV treatment on the sensory character of treated milk. The effect of UV treatment on the bacterial load of refrigerated raw farm milk, whey, and brine will also be investigated.

Milking System Clean-in-Place (CIP) Research

D.J. Reinemann*

Funding: Stearns Packaging

Cooperator: UW Biological Systems Eng.

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 Manuf.; UW Biological Systems Eng.

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 plasma 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 Manuf.; UW Biological Systems Eng.

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. Preliminary tests on bacteria have been initiated at the UW Medical School.

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 Biological Systems Eng.; UW Ctr. for Plasma-Aided Manuf.

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 to prepare surfaces with molecular recognition capabilities.

It was recently demonstrated in the lab 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 concentrates 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 Manuf.; UW Biological Systems Eng.

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.

Field Testing of Wood Fiber-Thermoplastic Composites

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

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 tests both above ground and in ground in Madison, Wisconsin, and Gulfport, Mississippi. The effects of UV radiation on specimens above ground are being evaluated to determine UV degradation of both the wood and the plastic. Mold growth on these specimens is also being studied. 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.

Natural Resources and Environment

Wisconsin Pilot of Dairy Environmental Management Systems

B.J. Holmes*, G.W. Jackson

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

Cooperators: UW Biological Systems Eng.; 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; USDA Dairy Forage Research Ctr.; UW-Platteville Pioneer Prairie Farm

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 was tested with dairy farmers in 2004. An advisory committee has been formed to encourage acceptance of AgEMS's by the dairy industry. An EMS is nearly complete at the UW Agricultural Research Station (ARS) in Marshfield, Wisconsin, and others have been started at the ARS in Arlington, at the UW-Platteville Pioneer Prairie Farm, and at the US Dairy Forage Research Center. By developing EMS's at these research facilities, we are gaining invaluable experience prior to working on EMS's on commercial dairy farms.

Dairy producers in Saint Croix, Manitowoc, and Calumet Counties have been introduced to EMS's. To date, one producer has indicated an interest in developing an ISO 14001-equivalent EMS so as to qualify to participate in the Wisconsin DNR Green Tier program. A second producer has begun to develop an EMS.

Development of Polymer Application Method for Water Clarification

A.M. Thompson*

Funding: UW Industrial and Economic Development Research Fund; gifts

Cooperators: UW Biological Systems Eng.; CFM, Inc.; Dane County Land Conservation Dept.

A common management practice for controlling sediment is the use of stormwater detention facilities. These facilities remove sediment from stormwater runoff by reducing discharge rates, thus 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 may require days to settle out, traditional stormwater detention facilities are not very effective at removing such particles from stormwater. Sediment-flocculating polymers can be used to accumulate and remove suspended sediment from stormwater, thereby 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 were conducted to determine the effect of: polymer molecular weight; polymer concentration; calcium, aluminum, and citrus acid additives; mixing speed; and sediment concentration on removal of suspended sediment.

New Polymer Technologies for Controlling Soil and Phosphorus Loss from Farm Fields

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

Funding: Gifts

Cooperators: UW Biological Systems Eng.; UW Soil Sci.; Soil Net LLC.

Management practices to reduce soil loss from agricultural fields are vital for sustaining crop productivity and for preventing nutrients that are adsorbed to soil particles from reaching waterways. In order to meet strict environmental standards and still earn a living, producers need cost-effective management practices for reducing soil and phosphorus (P) exports from their fields. The goal of this study is to determine the ability of four new polymer technologies on reducing soil and P loss from conservation tillage and no-till farm fields. The new technologies have the potential to overcome the two major impediments to polymer success/acceptance in rainfed regions:

1. the high application rates required and corresponding high cost, and
2. the labor and water required to dissolve polymers and maintain a low viscosity solution for spraying.

Specifically, the polymer formulations show promise for effectiveness at low application rates and are highly soluble in water. Combined, these aspects will reduce the labor, water and cost required for effective soil and P control.

Rainfall simulation experiments were conducted at the UW Agricultural Research Station in Arlington, Wisconsin, during fall 2004. A liquid emulsion of polymer and inorganic salts, water, oil, and surfactant was applied to the soil (silt loam) surface at rates of 2.5 kg/ha and 5.0 kg/ha. At the 5.0 kg/ha application rate, sediment concentrations were reduced by 68-88% compared to controls, and total P was reduced by 51-71% compared to controls. At 2.5 kg/ha, reductions were roughly half those observed for the higher rate. The plots are still in place. Rainfall simulations will be conducted this coming year to evaluate the longevity of the applied polymer. Laboratory experiments are being conducted to screen the additional polymer formulations and to guide future field experiments.

Effectiveness of Urban Lawns to Hydrologically Disconnect Impervious Areas

A.M. Thompson*

Funding: Wis. Dept. of Natural Resources

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

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. One season of field experiments on residential lawns in Madison, Wisconsin, has concluded. The first season focused on simulated lawn run-on from rooftop downspouts. We have modified a continuous simulation groundwater recharge model, RECARGA, to predict the run-on/runoff response of urban lawns. Field data was used to validate the model. A second season of field experiments is planned on an additional set of urban lawns in Madison.

Evaluation and Mitigation of Thermal Pollution in Landscapes

A.M. Thompson*

Funding: USDA Hatch

Cooperators: UW Biological Systems Eng.; UW Soil Sci.; 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. During a rainfall/runoff event, runoff absorbs some of that heat energy and is warmed. The higher runoff temperatures can raise the temperature of the receiving waters. Stream temperature is a major limiting factor for cold-water fisheries. Increases in water temperature can result in biological impairment to aquatic habitat.

A field study has been conducted at the UW West Madison Agricultural Research Station to:

1. study increases in pavement temperature and the subsequent transfer of heat to stormwater runoff, and
2. compare the hydrologic and thermal response of similarly sized areas of asphalt and sod.

Asphalt and sod plots (50×30 ft) have been instrumented to measure rainfall intensity and spatial depth, wind speed, solar radiation, air temperature, rainfall temperature, pavement temperature at various depths and locations, sod temperature at various depths and locations, soil moisture, runoff temperature and flow rate. The system is designed to capture both natural and simulated rainfall/runoff events. One season of simulated field experiments has been conducted. A second season of field experiments is planned. Data from the field experiments will be used to validate the Thermal Urban Runoff Model (TURM).

Rock cribs are a current mitigation strategy used to reduce runoff temperature prior to runoff entering thermally sensitive waters. A laboratory study has been conducted to quantify the effectiveness of a rock crib on reducing runoff temperature. The effectiveness of rock cribs depends on the influent temperature, the initial crib temperature, the amount of water in the crib prior to stormwater entering the crib, and the size of the crib. Results from the laboratory experiments have been used to validate and modify a numerical routine within TURM that predicts heat transfer between the stone and the water and ultimately the effluent water temperature. The model will be used to develop design standards for using rock cribs as temperature reduction devices.

Infiltration and Pollutant Removal Capacity of Engineered Soils for Use in Urban Bioretention Basins

A.M. Thompson*

Funding: UW Graduate Sch.

Cooperators: UW Biological Systems Eng.; Wis. Dept. of Natural Resources

Bioretention is a relatively new management practice for treating urban stormwater. A bioretention basin is a gravity flow system with a combination of plants, mulch, and engineered soil. Piping at the base allows drainage. Stormwater runoff is focused into and temporarily stored in the basin, allowing contaminated water to infiltrate through the engineered media. Physical, chemical, and biological processes treat this water as it filters through the media. After passing through the media, the water either infiltrates into the adjacent native soil where it can enhance groundwater recharge, or excess water is discharged to a stable outlet. The engineered soil is a mixture of sand, soil, and compost. The goals of this study are to determine the infiltration rates and the pollutant removal capabilities of engineered soils. Laboratory experiments using flow-through columns are being conducted on engineered soils with percentages of sand, soil, and compost ranging from 30-60%, 20-50%, and 20-50%, respectively, Flow-through studies using synthetic stormwater are planned to determine temporal variability in pollutant removal rates from the same engineered soil mixtures.

Restoration of a Drained Lake Basin at Franbrook Farm

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

Funding: UW College of Agric. and Life Sciences; UW Sch. of Natural Resources; UW Graduate Sch.

Cooperators: UW Biological Systems Eng.; 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, these reservoirs often serve as areas of sediment accumulation and deposition. Following 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.

In January 2003, the Wisconsin Department of Natural Resources drained a 3-ha, 40-year-old pond in southern Wisconsin. This basin provides the setting for this research on re-establishing native prairie vegetation. The study is designed to gain quantitative understanding of how these 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 and total porosity, particle size distributions, and volumetric water content spatially throughout the basin. Experimental plots will be seeded in the spring of 2005. We are also investigating the effects of crack formation within the top layer of deposited sediment on water movement through the basin.

Surface Water Quality Impacts of Management Intensive Rotational Grazing

A.M. Thompson*, F.W. Madison, J.O. Peterson

Funding: USDA Natural Resources and Conservation Service; UW Ctr. for Integrated Agric. Systems; Wis. Dept. of Agric., Trade, and Consumer Protection

Cooperators: UW Biological Systems Eng.; UW Soil Sci.; UW Agronomy

Management Intensive Rotational Grazing (MIRG) is a farming system that has grown in acceptance in Wisconsin. Herd sizes are increasing, and animals are being overwintered in a variety of settings, some of which may create environmental problems. The objective of this project is to further our understanding of the environmental impacts of MIRG through quantification of sediment and nutrient loads (nitrogen and phosphorus) from overwintering areas. Two research sites representing different soil and physiological regions in Wisconsin have been selected: the Breneman Farm located in Columbia County and the Klessig Farm located in Manitowoc County. Both farms are part of the Discovery Farm program. Soils on the Breneman and Klessig farms are coarse-textured and red clay, respectively. Spring snowmelt and runoff are collected down slope of the overwintering area on each grazing farm.

Use of Cold Plasma to Functionalize Fibers for Filtration Research

F.S. Denes*, R.M. Rowell*, C.G. Hunt

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

Low-pressure, non-equilibrium plasma modification of the surface of wood fibers to improve their ability to absorb contaminants from water is the main objective of these investigations. A small rotating plasma-reactor is considered to 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. These research investigations are performed in collaboration with PPL-Madison and industrial partners for the evaluation of scaling-up possibilities of the plasma technology.

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

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

Funding: USDA Forest Service; Wayne Natl. Forest
Cooperator: Wayne Natl. 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, 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 show 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 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 Eng.; USDA Forest Service

Inorganic/organic hybrid adsorbents to remove orthophosphate from water were prepared by dispersing inorganic Lanthanum (La) onto *Juniperus monosperma* bark through wet impregnation. The La was anchored onto the bark by ion-exchange with calcium and played an important role in removing orthophosphate from water. Two La precursor concentrations (0.1, 0.01 M) were used, resulting in fiber loadings of 0.198 and 0.302 mmol La/g, respectively. La exhibited a strong affinity for the bark at circum-neutral pH conditions, whereas significant La dissolution occurred below pH 4.5. For the high La loading, La dissolution was 86% and 0.1% at pH 2.5 and 7.3, respectively. Initial La loading onto bark significantly influenced its orthophosphate sorption capacity, which was determined to be 0.177 and 0.303 mmol P/g from sorption kinetics, and 0.188 and 0.233 mmol P/g from sorption envelope, respectively. Based on sorption capacities, the P-to-La molar ratio on the bark surface was extremely high (0.89-0.95 for the low La loading sample and 0.77-1.00 for the high La loading sample, respectively), implying that orthophosphate removal occurred by other mechanisms in addition to adsorption. From the orthophosphate surface loading levels and the shape of the sorption isotherms, it appears that adsorption occurs at low sorbate-to-sorbent (P to treated juniper bark) ratios and changes to surface precipitation at higher ratios. Spectroscopic results from X-ray diffraction and diffuse reflectance infrared Fourier transformation supported the conclusion that surface precipitation mechanisms are responsible for orthophosphate removal by La-impregnated lignocellulosic materials.

A Spatially Distributed Phosphorus Module of the Precision Agricultural-Landscape Model: Description, Calibration and Verification

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

Funding: USDA Natl. Integrated Water Quality Program, Integrated Research, Educ. and Ext. Applications
Cooperators: UW Biological Systems Eng.; UW Soil Sci.; Wis. Discovery Farms Program; UW Agric. Research Stations

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 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.

Corn Residue Level and Manure Application TIming Effects on Runoff and Sediment Losses

K.G. Karthikeyan*, J.D. Grande, P.S. Miller, J.M Powell

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

Interest is growing in evaluating the effect of corn silage harvesting methods for erosion control. Increasing silage cutting height increases residue cover and could conceivably minimize off-site migration of sediments compared to conventional silage harvesting. The effects of residue level and timing of manure application on runoff and sediment losses from no-till corn were examined. Treatments included conventional corn grain (G) and silage (SL) and non-conventional, high-cut (60-65 cm) silage (SH). Corn harvesting treatments were subjected to different manure application regimes: surface application in fall (F) or spring (S) or no manure (N). Simulated rainfall (76 mm/h; 1 h) was applied in spring and fall for two years (2002, 2003), runoff from 2- × 1.5-m plots was collected, and a subsample was analyzed for sediment concentration and aggregate size distribution. Runoff volume was inversely related to residue cover. Adding manure to silage plots reduced spring runoff by 71-88%, attributable to an increase in soil organic matter content, compared to SH-N and SL-N. Differences in sediment concentration between SH and SL were not significant. For silage plots, spring-applied manure had the greatest influence on sediment export, reducing it by 84-93% in spring runoff compared to corresponding N plots. Sediment loads were also 85-97% lower from SH-S compared to SL-N in all four seasons. Except for spring 2003, sediment export from G was lower than from SL. The combination of manure and higher residue associated with high-cut silage often lowered sediment export compared to low-cut silage. Nearly identical aggregate particle size distributions were observed in sediments from SH and SL plots. High residue levels, combined with spring-applied manure, led to enrichment in the clay-sized fraction of runoff sediment. Recently-applied manure and higher residue levels achieved by high-cutting silage can substantially lower sediment losses in spring runoff when soil is most susceptible to erosion.

Corn Residue Level and Manure Application Timing Effects on Phosphorus Losses in Runoff

K.G. Karthikeyan*, J.D. Grande, P.S. Miller, J.M. Powell

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

Increasing interest in using corn silage on Wisconsin dairy farms may have implications for nutrient losses from agricultural lands. High-cut silage can result in higher quality feed and may provide more residue cover after harvest, thereby reducing off-site nutrient losses compared to harvesting conventional corn silage. We examined the effects of residue level and manure application timing on phosphorus (P) losses in runoff from no-till corn. Treatments included conventional corn grain, conventional cut (10-15 cm) silage, and high-cut (60-65 cm) silage and three manure treatments (no manure, spring, or fall application). Simulated rainfall (76 mm/h; 1 h) was applied in spring and fall for two years (2002, 2003), runoff from 2- × 1.5-m plots was collected, and subsamples were analyzed for dissolved reactive P (DRP), total P (TP), and P mass distribution in four particle size classes. TP and DRP loads were inversely related to percent residue cover, but both TP and DRP concentrations were unaffected by residue levels. Manure application increased DRP concentrations in spring runoff by two to five times but did not significantly affect DRP loads; higher DRP concentrations were offset by lower runoff volumes. Spring manure application reduced TP loads in spring runoff by 77-90% compared to no manure plots; the extent of reduction was greatest at the lowest residue levels (< 40%). TP concentration in sediments increased as particle size decreased. Adding manure increased the TP concentration of the 0-2 μm fraction by 79-125%, but elevated the 2-10 and 10-50 μm fractions to a lesser extent. Recent manure additions were most influential in enriching transported sediments with P. Cutting silage higher increased residue cover, but often was insufficient to lower nutrient loss in runoff. However, manure addition, in conjunction with higher residue levels, did not significantly reduce P losses from corn fields harvested for silage.

Storage of Sediment and Particulate-Bound Phosphorus in an Agricultural Landscape

K.G. Karthikeyan*, P.E. Cabot, P. Novak, R.C. Lathrop

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

This study fosters more effective landscape targeting of non-point pollution by analyzing sediment and phosphorus (P) accumulation in landscape "depressions". These depressions are of particular interest in studying P delivery from farm fields because they may be acting to reduce the overall watershed area that contributes to non-point source pollution. Thus, the study elucidates the disproportionate influence of specific landscape features by abetting or mitigating non-point source pollution.

The purpose of the study is to derive relationships between the rates and quantities of sediment deposition and P accumulation within agricultural landscapes where non-point delivery of P has been deemed an environmental problem. The focus is on landscape depressions that drain internally during small storm events but may overtop during larger events or under conditions where soil permeability is low (e.g., frozen during winter). These depressions range in size, but the focus is on those occupying 1-10 ha and collecting runoff from catchments approximately 10 times larger. Soil cores were taken with a truck-mounted coring machine, which penetrated to a depth of 1 m or more until encountering bedrock. Soil cores were then sectioned by depth into increments of 0-1, 1-2, 2-5, and 5-10 cm and then every 10 cm to the bottom of the core. Samples from each section were

analyzed for total P, equilibrium P concentration, naturally occurring radioisotopes (Cs-137, Pb-210, K-40), and texture. Temporal patterns of sediment aggradation will be estimated from isotope activities and compared to monitored sediment transport patterns during snowmelt and rainfall and runoff events.

Linking Sediment Transport Mechanisms and Contributing Source Areas to Water Quality Impacts

K.G. Karthikeyan*, P.S. Miller, P.D. Gaebler; S.B. McClure; J.D. Grande; P. Whiting

Funding: USDA Natl. Research Initiative

Cooperators: UW Biological Systems Eng.; UW Agric. Research Stations; Case Western Reserve U.; USDA Agric. Research Service

A comprehensive monitoring and measurement study is being conducted using complementary in-field and edge-of-field sampling techniques to gain a better understanding of sediment transport processes within the site and to characterize off-site losses of sediments and associated nutrients. In-field sampling involves collecting soil cores to determine radioisotope (Be-7, Cs-137, Pb-210) activities and down gradient (from application area) soil rare earth element (REE) concentration and to record runoff saturation sensor readings. Runoff collected at the bottom of hillslope (edge-of-field) will be characterized for different sediment properties and phosphorus (P) distribution.

Paired hillslopes in an active agricultural field are being fitted with surface runoff sensors to identify hydrologically active areas (HAA) within which REE-tagged soils and radiometric fingerprinting will be employed. We have installed six water quality monitoring stations on three paired hillslopes. Contrasting management practices were chosen to produce extremes in: a) residue cover and random roughness (corn harvested for grain *vs*. silage), b) crop row orientation (tillage following contours *vs*. up-and-down tillage), and c) manure management (with and without fall manure application). The above practices are expected to produce significant differences in the underlying soil erosion processes and subsequent sediment and transport. Runoff sensor development is complete (improved version of an existing design), and more than 200 sensor boards have been built and are being calibrated. Runoff sensor mounts have been installed on one hillslope. Currently, we are integrating the sensors with our data logger systems and are performing pre-installation tests. The sensor networks will be installed in all six hillslopes in spring, 2005. We have begun the process of REE-tagging of soils from the hillslopes for our particular application.

An optimal hillslope length fully encompassing the HAAs, upstream from the edge-of-field, will be selected for placement of REE-tagged soils. Characterization of areas of soil erosion will occur by several means: a) applying and monitoring REE-tagged soils, b) measuring changes in Be-7 inventory, and c) mapping the rill network. The migration of labeled soils will be used to quantify sediment transport rates and distances and to delineate source areas. Radiometric fingerprinting will help elucidate underlying erosion mechanisms. Monitoring the redistribution of REE-tagged soils will quantify the source regions of suspended sediment and characteristic transport distances. Radiometric fingerprints using concurrent measurements of multiple environmental isotopes will be used to determine relative area extents of the hillslope subjected to inter-rill *vs*. rill erosion. Erosion depths and mechanisms will be evaluated by mass-balances of radionuclide tracers in soil and runoff. We will apply these various tools after multiple storm events during two growing seasons.

Measuring and Modeling the Source, Transport and Bio-Availability of Phosphorus in Agricultural Watersheds

K.G. Karthikeyan*, P.E. Cabot, J.C. Panuska, P. Novak, R.C. Lathrop

Funding: US Environ. Protection Agency (STAR Program)-Nutrient Sci. for Improved Watershed Mgmt. Program

Cooperators: UW Biological Systems Eng.; UW Civil and Environ. Eng.; UW Forest Ecology and Mgmt.; UW Rural Sociology; UW-Platteville; Wis. Dept. of Natural Resources; UW Agric. Research Stations

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. Firstly, 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. Secondly, 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 able to capture runoff from fields comparable to the size farmers actually manage. Finally, we will use manure management as a research variable at the scale that farmers manage animal manures.

Sediment and P delivery from alfalfa swards (0.01-0.033 ha) were monitored during natural runoff events. Total solids (TS) were "standardized" by rainfall erosivity. Standardized TS and particulate P loads generally increased during secondary storms (successive storms following an initial event in a series). These increases were attributed to progressive erodibilty of the soil surface. Erodibility increased regardless of the erosive power of secondary storms. Results from a series of events following manure application were examined using exploratory data analysis approaches. Increase in the fraction of clay-sized ($< 2\ \mu m$) particles in runoff suggested that broadcast manure application did not significantly prevent soil surface degradation; the initial storm occurred just one day after manure application. The onset of this storm shortened the contact time, or incubation period, between manure and soil. Decreasing ratio of volatile to total solids, accompanied by increasing fraction of clay-sized particles, suggested that "manure particulates" were exhausted from the surface by the first few events following manure placement. Other findings included:

1. Significantly greater dissolved reactive P (DRP) concentration during late season events and one day after manure application;
2. Declines in DRP and total dissolved P concentration with increased TS delivery;
3. Diminishing ratio of DRP to total P with each successive event after manure placement.

Erodibility of exposed soils on alfalfa fields immediately after hay cutting requires further research. Risks of broadcast manure placement on alfalfa fields should also receive due planning consideration.

In addition, natural runoff samples are being collected from three hydrologically isolated hillslope tracts (3.7 $\times$ 36.6 m) at the UW Arlington Agricultural Research Station using bulk overland flow samplers. Each field was planted in corn (with conservation tillage – fall chisel plow) but have extremes in residue cover created by different harvesting schemes: grain (high residue), silage (low), and silage with fall manure application (intermediate). Runoff samples are being analyzed for TS, volatile solids, particle size distribution (5 discrete size classes by gravity sedimentation: < 2, 2-10, 10-50, 50-500, > 500 μm; continuous size distribution using laser diffraction), different forms of P (dissolved *vs*. particulate-bound), and P mass distribution in different size classes. In addition, unique information on the stability of aggregates transported by rill flow under these contrasting agricultural management systems will be presented. Relevant comparisons of particle size distributions and P mass in different size classes will be performed against off-site sediment and P loss measurements collected within the same farm using plot-scale simulated rainfall experiments (dominated mainly by inter-rill flow).

Comparing Trends of Snowmelt and Storm Runoff Sediment and Phosphorus Losses from Agricultural Fields in Wisconsin

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

Funding: USDA Natl. Integrated Water Quality Program, Integrated Research, Educ. and Ext. Applications

Cooperators: UW Biological Systems Eng.; UW Soil Sci.; Wis. Discovery Farms Program

Phosphorus (P) losses from agricultural fields are becoming a critical concern due to increasing soil test P (STP) values across the state and significant degradation and eutrophication of the state's water bodies. Traditional approaches to P management and watershed biochemical methane potential (BMP) development focus on agronomic practices during the growing season. However, these systems may behave differently during environmental conditions when snowmelt and rainfall on frozen ground can occur. Since snowmelt processes and their effects on the fate and transport of P are poorly understood, their importance considering overall P losses from Wisconsin's fields is unknown.

Hydrology and water quality data have been collected from six locations across the state with multiple sites in each location featuring numerous agronomic practices, crop types, matrix soils, manure and inorganic fertilizer inputs, and background STP values. Watershed scales for the sites range from sub-field areas (0.1 ha) to multiple field watersheds on the order of 16 ha. Preliminary results indicate that dissolved reactive P (DRP) losses and DRP:TP ratios are greater in snowmelt, especially from fields receiving P inputs in the previous fall. In addition, no-till fields contribute the most runoff during snowmelt events, whereas tilled fields generally have increased runoff volumes during storm events. P losses followed these trends, indicating that snowmelt runoff may reduce the P management benefits of some cropping systems if one considers the influence of the snowmelt season during BMP evaluation.

Solution and Nitrogen Dynamics in Soils Receiving Chemically Treated Manure

K.G. Karthikeyan*, M. Kalbasi, P.S. Miller

Funding: Wis. Fertilizer Research Council

This study attempts to bridge the gap between our knowledge of chemical treatment systems for dairy manure and the ultimate fate of nutrients (N and 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 impacts. Our findings are critical for designing any chemical treatment and land application system, which will provide increased options to manage dairy manure.

An incubation study was conducted to determine the effect of chemically treated (three treatments: alum-Al; $FeCl_3$-Fe; CaO-Ca) manure addition on short- and long-term N dynamics in soils. Two manure 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^- ($WENO_3$), NO_2^-, and K^+-extractable NH_4^+ after 1 d, 1 and 2 wk, 1, 3 and 6 mo, and 1 and 2 yr. Soil pH increased significantly only for the application of Ca-treated manure after all incubation periods and was sensitive to the application rate. However, soil pH decreased sharply between 1 d and 1-2 wks or remained unchanged (compared to control) for the other treatments. Nitrate release was controlled by the treatment type (untreated > chemically treated manure > control) and increased sharply between 1 d and 1 wk and then slowly at longer incubation periods. Based on the percent of applied inorganic N released as $WENO_3$ (P_{WENO3}), differences between chemical treatment types mostly followed this order: untreated > Al-treated > Ca-treated > Fe-treated. Doubling the manure application rate had no effect on P_{WENO3}. The trend in EC followed that of $WENO_3$, resulting in an excellent correlation ($r^2 = 0.96$) between the two variables. In contrast to NO_3^-, K^+-exchangeable NH_4^+ decreased sharply between 1 d and 1 wk and then remained relatively constant for up to 2 years. Untreated manure had the highest ratio of exchangeable NH_4^+ to applied inorganic N after 1 wk, and the differences between chemical treatment types were insignificant. Application of chemically treated (especially Fe- and Ca-treated) manure appears capable of decreasing the extent of initial (up to 1 wk) rapid nitrification. Besides short-term effects, adding $FeCl_3$ is effective in lowering $WENO_3$ even after 2 years of incubation.

Influence of Anaerobic Digestion on Dairy Manure Phosphorus Extractability

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

Funding: USDA CSREES; Hatch

On-farm anaerobic treatment is used to remove solids, odor and pathogens and to recover energy. Little information is available on the effect of this treatment method on phosphorus (P) dynamics. The objective of this study was to investigate the effect of different inoculum-to-substrate ratios (ISR) on P extractability from anaerobically digested dairy manure. Dairy manure (substrate) and anaerobically digested dairy manure (inoculum) were collected from a full-scale, on-farm anaerobic digester. High ISR (HIS; ISR = 2.0) and low ISR (LIS; ISR = 0.3) samples were prepared on a volatile solids (VS) basis. These samples were subjected to mesophilic (35°C) anaerobic digestion in batch reactors without mixing for 120 d. Specific methane yield, TS, and VS removal were higher in the LIS system compared to the HIS system. Serial and repeated extraction methods were used to characterize P extractability. Deionized (DI) water and $MgCl_2$ were used as extractants in the serial extraction method with extractant-to-manure ratios (EMR) ranging from 3 to 127. For repeated extraction, manure was extracted six times with DI water (EMR = 3). While anaerobic treatment decreased water-extractable P (WEP) in LIS extracts at EMR values of 3 and 7 by 28% and 24%, respectively, a significant increase (40%) in WEP occurred at an EMR of 3 at HIS. WEP in all other serial extracts of treated manure was higher regardless of ISR and EMR. Extractability of P increased sharply up to the third extraction step, after which it leveled off. The effectiveness of anaerobic digestion at LIS to reduce P extractability was also observed up to the second extraction step. In contrast, the digested manure always produced higher WEP levels for the HIS system. Our results indicate that, depending on the ISR used, anaerobic digestion of dairy manure can increase or decrease manure P extractability and hence its availability in runoff. However, it appears that this impact could be more pronounced under conditions where low runoff volumes are generated and for the first few precipitation events after land application of manure.

Probable Phosphorus Solid Phases and their Stability in Anaerobically Digested Dairy Manure

K.G. Karthikeyan*, K. Gungor

Funding: USDA CSREES; Hatch

Solid phases determining phosphorus (P) extractability from anaerobically digested dairy manure have not been investigated in detail. The objective of this study was to elucidate the dominant inorganic P phases controlling P solubility and to evaluate their stability after anaerobic digestion using geochemical equilibrium modeling with Mineql+. Mineql+ simulations were performed using chemical composition data obtained by subjecting both untreated and anaerobically digested manure to two independent deionized water extraction methods, serial and repeated extractions. The serial and repeated water extractions are intended to mimic the effect of single and consecutive storm events, respectively. Serial extractions consisted of single-step extractions with extractant to manure ratios (EMRs) ranging from 3 to 127 (wet mass basis), and repeated (6-step) extraction had an initial EMR of 3. Mineql+ simulations of the water extracts showed that struvite ($MgNH_4PO_4.6H_2O$), β-tricalcium phosphate (β-TCP), and octacalcium phosphate (OCP) were the probable phases controlling P solubility. Anaerobic digestion did not significantly change P release trends and the type of predominant inorganic P solid phases. Overall, there was good agreement in the Mineql+ simulation results for manure extracts obtained from the two independent water extraction methods. Initially (low runoff volumes and first few runoff events after land application), P solubility appears to be controlled by more soluble P solid phases, mainly struvite, after which (for large and later runoff events) sparingly soluble phases, such as OCP/β-TCP-like phases, exert their influence on P release from anaerobically treated dairy manure.

Sorption of Tetracycline and Fluoroquinolone Antibiotics to Inorganic Mineral Surfaces

K.G. Karthikeyan*, C. Gu, J.A. 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 Eng.; UW Soil Sci.

Antibiotics are used extensively in human therapy, veterinary medicine, and as animal husbandry growth promoters. Recent detection of antibiotics in surface and ground water has raised concerns about the presence of these emerging contaminants. Our recent Wisconsin statewide survey detected eight compounds in five classes with the order in frequency of detection being: tetracycline and trimethoprim > sulfonamides > macrolides > fluoroquinolones. 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.

The effect of solution chemistry (pH, sorbate-to-sorbent ratio, ionic strength) and reaction time on the sorption of tetracycline to the hydrous oxides of Al (HAO) and Fe (HFO) was examined. Sorption to HAO increased with increasing pH up to pH 7 (no such trend for HFO) above which it decreased at higher pH values for both HAO and HFO. Experimental results indicate that ligand-promoted dissolution is occurring during tetracycline sorption to these hydrous oxides. Ligand-promoted dissolution was more significant for HAO than HFO, attributable to the difference in labile surface sites between these two sorbents. The ability of tetracycline to form strong complexes with Al and Fe will increase the solubility of these minerals. Sorption of tetracycline was quite rapid, and equilibrium was achieved after 8 h. However, soluble metal (Me: Al or Fe) concentrations attained equilibrium only

after 24 h. Ligand-promoted dissolution appears to be a two-step process. Initially 1:1 Me-tetracycline soluble complexes are formed and, as the reaction progressed, 2:1 complexes existed. Increasing ionic strength (from 0.01 to 0.5 M) decreased the sorption extent only at higher sorbate-to-sorbent ratios, which suggests the dominance of inner-sphere type complexes at low equilibrium tetracycline concentrations. Spectroscopic evidence indicates that tricarbonylamide and carbonyl functional groups of tetracycline could be responsible for sorption to mineral surfaces. Our findings will increase understanding of the environmental occurrence, fate, and transport characteristics of antibiotics which are regarded as emerging organic contaminants.

Structures / Construction

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 Eng.; 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 and 2004 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, 22 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. This experimental design was replicated twice for a total of 440 building tests in 2002. During each test, signals from 225 different transducers were recorded every 4.7 s. With a test time of at least 3 min., each loading usually generated at least 10,000 data points, obviously 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-s 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 latter part of 2003 and throughout 2004, research effort was dedicated to modeling full-scale building behavior. In the end, a model with three displacement degrees of freedom (DOF) per building frame was selected. These include a displacement parallel to the frame and two displacements perpendicular to the frame – one at each sidewall. The 3-DOF/frame model contains four different simple spring elements (a.k.a. truss elements): a frame element, a roof cladding element, a chord element, and a wall cladding element.

The primary task during the modeling phase of the study was to determine axial stiffness properties for each of the four elements or, more specifically, to find element stiffness values that were a function of building configuration and thus could be used to accurately predict full-scale building behavior regardless of building configuration or distribution of applied loads. This turned out to be a formidable task, requiring thousands of computer simulations because of the interdependency of wall cladding, roof cladding, and chord force element properties. Nevertheless, a set of element properties was selected that do a very good job of predicting building displacements as well as the in-plane bending moment and shear forces between building bays. The results of this modeling were presented at the 2004 ASAE/CSAE International Meeting in Ottawa, Ontario.

The 3-DOF/frame model is embodied in computer program DAFI3 (Diaphragm and Frame Interaction 3dof/frame). Once a pre- and post-processor are added to the program, it will be made available to the general public.

Accuracy of Corrugated Metal Panel and Trim Installation

D.R. Bohnhoff*, D.K. Cockrum

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

In January of 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.

In March of 1999, the NFBA Technical and Research Committee proposed that NFBA pursue the development of a second construction tolerances document, one that covered metal trim and corrugated panel installation. In October of 2002, the committee identified items to include in the document. At this same meeting, it was agreed that UW-Madison researchers would conduct the field research required for document development.

Actual data collection commenced during the summer of 2003 and was completed in early June, 2004. A total of 52 buildings were surveyed. Items investigated included: (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

and scrapes; (12) crimps/kinks; (13) horizontal fastener alignment; (14) fastener drive depth; (15) fastener driving angle; (16) fasteners missing framing; (17) irregular fastener patterns.

Data from field investigations were tabulated and then summarized in a technical paper presented at the 2004 ASAE/ CSAE International Meeting in Ottawa, Ontario. This information was subsequently used by Professor Bohnhoff to draft the first version of a document entitled *Accepted Practices for Post-Frame Building Construction: Metal Panel and Trim Installation Tolerances*. The final version of this document is slated for completion in 2005.

Post Installation Tools

D.R. Bohnhoff*

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

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 (Badger Post-Hole Leveler, Badger Cookie Cart, Badger Post-Hole Installation Shield) were developed and tested in 2003. Research in 2004 concentrated on refining the Badger Post-Hole Leveler design.

The Badger Post-Hole Leveler (PHL) levels soil at the base of a hole prior to tamping and placing a precast concrete footing (a.k.a. cookie). Use of such a device becomes increasingly important as footing diameter increases. It is difficult to ensure that the base of a hole is not tilted or uneven without such a device. 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.

Several different PHL designs were fabricated and tested in 2004, but the design that was ultimately selected was not that different from the original prototype. Key features of this design include cutting edges at 90 degrees to leveling/support "spokes", a centering/pivot point, and interchangeable heads to facilitate different size footings and storage. The PHL seems to work well in all soil types. The Badger PHL will be introduced to an international audience at the 2005 ASAE International Meeting.

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 involved.

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.

Development of New Treating Equipment Based on Roller Pressing

R.M. Rowell*, M. Inoue*

Funding: Wood Research Inst. (Kyoto, Japan)

Green lumber can be pressed between two rollers to remove water from the wood. The wood will recover to its original thickness after pressing. The roller press can also be used to treat wood with chemicals by immersing the press in the treating solution. The chemical is sorbed by the wood in the thickness recovery process.

Development of Wood Fiber-Thermoplastic Composites

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

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

R.M. Rowell*, G.C. Chen

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 Advanced Wood Fiber-Based Composites Based on Fiber Modification

R.M. Rowell*, R. Ibach

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 of the technologies 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.

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 written 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.

Midwest Intervention Evaluation Pilot Project

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

Funding: US Centers for Disease Control and Prevention; Natl. Inst. for Occupational Safety and Health via Ohio State University's Great Lakes Ctr. for Agric. Safety and Health

Cooperators: UW Biological Systems Eng.; various Wis. grower organizations; UW Coop. Ext. Service

This project will develop background information and prepare for a full-scale application for funding to intervene in the landscape sector of the agricultural industry in the Great Lakes states. Our intervention strategy will encourage adoption of production practices that are more profitable as well as safer. We plan to accomplish two specific aims.

1. Learn from landscape operation growers and landscape industry resource people about the landscape industry, including work activities, job hazards, candidate safer and more profitable work practices and tools, and sources for a sampling frame of landscape operations in the Great Lakes states.
2. Learn from previously published research and on-going projects about the landscape industry, including work activities, job hazards, candidate safer and more profitable work practices and tools, and sources for a sampling frame of landscape operations in the Great Lakes states.

We believe that this study plan will yield useful information for a future NIOSH application about a planned intervention with the landscape industry.

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 Eng.; 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).

Wisconsin Dairy Traumatic Occupational Injury Intervention

L.J. Chapman*, A.C. Newenhouse, 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 Eng.; 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 plan to 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.

Electric Power and Energy Systems

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 Environ. Eng.; UW Dairy Sci.; UW Biological Systems Eng.

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 new methods in biology known as array hybridization, we will assess the effect of electrical exposure on messages produced in the immune system. This method allows access to assess several thousand messages in a single sample. Unlike other studies in which relatively few measurements are taken, this method allows us 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, these 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 Eng.; 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.

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

Quaternary ammonium and phosphonium functionalities have been successfully implanted onto various substrate surfaces using cold plasma technologies. Preliminary results indicate that the plasma-modified substrate surfaces exhibit significant antibacterial characteristics.

Iodine-containing amylase (starch) layers were also cross-linked using low-pressure non-equilibrium RF-plasma to trap halogen atoms into the polysaccharide structure. It was shown that the plasma-generated thin layers exhibit strong bactericide behavior.

Retention of silver atoms and silver nanoparticles into plasma-modified polysaccharide structures is also being considered to generate antibacterial surfaces.

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 Manuf.; UW Biological Systems Eng.; 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 bacterial 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 has been 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 has been 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 Manuf.; UW Biological Systems Eng.

Cooperators: UW Sch. of Veterinary Med.; 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.

Recently nitrogen atoms containing carbon-based nanoparticles were also DMP-synthesized to avoid particle agglomeration in *in vivo* applications. These particle systems are currently under testing in UTA laboratories.

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 RF-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 surface layers are being investigated to evaluate their potential applications in preparing robust bioactive surfaces.

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 Manuf.; UW Biological Systems Eng.

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 bioactive materials.

Plasma-Enhanced Modification of Metal and Ceramic Surfaces Involved in Space Research Applications

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

Funding: Orbitec Co.-Wisconsin (SBI project)

The objective of these investigations is to plasma-synthesize hydrophilic and antibacterial surfaces that are involved in space program applications.

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 Manuf.; UW Biological Systems Eng.; Amer. Meat Inst.
Cooperator: UW Mechanical Eng.

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.

Use of Plasma Technology to Decontaminate Surfaces and Air in Food Processing Environments

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

Funding: Dept. of Homeland Security, Natl. Ctr. for Food Protection and Defense

Two original plasma tools (array electrode reactor and flat plasma reactor systems) are tested for disinfecting surfaces that come in contact with food in the processing environment.

Atmospheric Pressure Non-Equilibrium Plasma Surface Modification of Low Dimension Capillary Cavities Including Various Catheter Materials

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

Funding: Boston Scientific Co.-Minneapolis

Interior surfaces of plastic catheter tubes are plasma-modified using an original, continuous-flow system, atmospheric pressure, non-equilibrium plasma technology to generate controlled surface energy catheter wall characteristics.

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, as well as the fact that the materials being mixed are typically opaque and changing constantly with time. A tool ideally suited to exploring the effect of material properties and process geomtry on flow patterns and mixing effectiveness of mixing processes is Computational Fluid Dynamics (CFD). In CFD, numerical simulation is used in combination with particle tracking to calculate the velocity, pressure, and stress fields from the fundamental physics that describes the behavior of the system, and then uses that information to determine 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 CFD commercial software packages, such as Fluent and Polyflow by Fluent, Inc., have increased to the point that simulation of flow and mixing in realistic mixers and mixing processes in 3-D is entirely possible.

In this work, the Finite Element Method CFD package Polyflow is being used to investigate mixing processes using highly viscous materials 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. In addition, 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 work is underway using Fluent to model lactose crystallization in continuous and batch crystallization systems and to study the effects of geometry and mixing on the crystallization process in order to identify factors that will allow for better control of crystal size distribution in the finished product.

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 bu in 2003. It 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 bu 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 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 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.

Use of Plasma Technology to Decontaminate Surfaces and Air in Food Processing Environments

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

Funding: Dept. of Homeland Security, Natl. Ctr. for Food Protection and Defense

Two original plasma tools (array electrode reactor and flat plasma reactor systems) are tested for disinfecting surfaces that come in contact with food in the processing environment.

The Effect of Drying Temperature, Water Concentration, and Heating Rate on Gelatinization of Corn Starches

S. Gunasekaran*, F. Altay

Funding: Hatch Funds

Starch gelatinization depends on many factors, e.g., water content, heating rate, botanical source of starch, treatments applied to starch before gelatinization, amylose-amylopectin content of starch, etc. We are investigating the effect of the air temperature used to dry shelled corn on the quality of extracted starch. Our objectives are to investigate the effect of drying temperature on gelatization characteristics of corn starches in terms of thermal and rheological parameters and to determine the gelatinization kinetics of those starches. Several varieties of waxy and non-waxy corn starch samples extracted from corn harvested at a moisture content of 30% and dried at 20 and 100°C drying air temperatures were used. Starch gelatinization kinetics was studied via differential scanning calorimeter thermograms. Statistically significant differences were observed.

In Situ Solidification of Grape Pekmez

S. Gunasekaran*, A. Kaya, S. Ko

Funding: Gift Funds.

Pekmez is a concentrated and shelf-life extended form of grape juice. We investigated its material behavior and the effect of processing factors during its solidification using *in situ* rheometry and color measurement by computer vision. The pekmez (45.3-75°Brix) is a Newtonian product. As expected, its viscosity increased with increasing solids concentration and decreasing temperature. A simple model was proposed to describe the combined effect of concentration and temperature on pekmez viscosity. The color of pekmez changed from dark brown to white, depending on the processing conditions such as concentration and type of bleaching agent used and the mixing rate.

In Situ Structure Evolution during Heat-Induced Gelation of Whey Protein Isolate

S. Gunasekaran*, S. Ko

Funding: Hatch Funds

In situ sol-gel transition of β-lactoglobulin (BLG) induced by heating and concomitant changes in gel structure and rheological properties were investigated with confocal laser scanning microscopy, small-amplitude oscillatory shear, uniaxial compression test, and differential scanning calorimetry. The effects of four critical factors were studied.

1. pH of 2, 5 and 7;
2. protein concentration of 5, 10 and 15%;
3. salt (NaCl) concentration of 0, 0.1 and 0.3 M;
4. heating rate of 1, 5 and 10°C/min.

Some basic techniques were developed to quantify and visualize the time-resolved, *in situ* two-dimensional (2D) and three-dimensional (3D) microstructural characteristics of BLG gels. Confocal laser scanning calorimetry images were obtained continually during heating up to 95°C via a specimen temperature control device developed. The images were corrected for imaging errors such as z-axis alignment, light attenuation, noise, and uneven intensity of the micrographs. Subsequent 2D and 3D analyses of the images provided several objective image features such as protein aggregate area, perimeter, volume, and gelation temperature. These parameters were used as structural indices to study the effects of gel preparation conditions on properties of BLG gels.

Whey Protein Concentrate Hydrogels as Bioactive Carriers

S. Gunasekaran*, M.M. Ould Eleya

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

Two sets of heat-induced hydrogels were prepared from whey protein concentrate (WPC) at constant concentration of 15% (w/v) and different pHs (5.1 to 10.0) and next at constant pH of 10.0 and different concentrations (12, 15, 18%). At a given pH, the higher the protein concentration, the shorter the gelation time and the larger the equilibrium storage modulus (G'_∞) and failure stress. For a given protein concentration, gelation kinetics and mechanical properties of WPC hydrogels are strongly dependent on pH. The swelling behavior of WPC gels was studied at 37.5 ± 0.5°C. The equilibrium swelling ratio (SR) was minimum when the swelling medium pH was close to the isoelectric point (pI) of the whey protein. When the swelling medium pH was far away from pI (from 6.0 to 10.0), the SR increased. In particular, if pH was higher than pI, the swelling was highly pH-sensitive. The higher the WPC concentration used to prepare the hydrogel, the lower the SR. Controlled drug release properties of WPC hydrogels were studied using caffeine as the model drug. Consistent with the swelling behavior of the gels, the release was slower at lower medium pH (= 1.8) than at higher pH (= 7.5). The SR and drug release rate decreased significantly when the gels were surface-coated with alginate.

Microencapsulation and Oxidation Stability of Freeze-Dried Menhaden Oil Powder

S. Gunasekaran*, M.P. Richard, C. Sun

Funding: Gift Funds

Emulsions of menhaden oil and β-cyclodextrin (BCD) incorporating whey protein isolate (WPI) were freeze-dried to produce microencapsulated menhaden oil powder. WPI concentration, core-to-wall ratio, and storage temperatures were varied to evaluate their effects on microencapsulation efficiency (ME) and oxidative stability (OS) of menhaden oil powders. Peroxide value (PV) and anisidine value were measured to assess OS. Emulsion viscosity was measured before freeze drying as a complementary tool to evaluate effects of composition and process parameters. ME of the microencapsulated oil powder was significantly affected by the composition parameters. The emulsion with 15%

WPI exhibited an antioxidant activity based on the 30% BCD microencapsulation system. The PV increased with storage temperature due to high oxygen diffusion into the microencapsulated oil droplet. The 30% BCD + 15% WPI emulsion system with a core-to-wall ratio of 1:6 developed relatively higher ME of 74.2% and better OS compared to the same systems at core-to-wall ratios of 1:2 and 1:4. The results based on rheological measurements were consistent with those based on ME and OS. The statistical analyses indicated that the core-to-wall ratio might be the most important factor affecting ME and OS of menhaden oil powders.

Broadband Viscoelastic Spectroscopy of Cheese

S. Gunasekaran*, R.S. Lakes, A. Singh

Funding: Hatch Funds

Water in large blocks of cheese migrates during cooling under a temperature gradient and/or salt gradient. Though the temperature effects have been documented, the concomitant changes in cheese pH, calcium and salt level, etc., have not been studied. Based on the well-known effect of cheese curd pH, the amount of colloidal (bound) calcium present in cheese and its associated changes in cheese matrix structure and water binding may be used advantageously to mitigate the temperature gradient-induced moisture migration. We are investigating such effects as the amount of bound calcium, pH, salt and temperature gradient, extent of proteolysis, and moisture and fat content.

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 Eng.; 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 in 2004 were to:

- Determine the fractional yield and moisture (grain, leaf, cob, husk, stalk) of leafy and low lignin varieties of corn during senescence and prior to harvest;
- Modify the grain combine harvester to allow single-pass harvesting of the grain and stover fractions in separate crop streams;
- Assess the fractional yield and moisture of stover when harvesting with this machine;
- Use NIR techniques to quantify the yield of important crop constituents when harvesting with this machine;
- Assess the storage characteristics of wet stover harvested with this machine;
- Begin a preliminary study of the potential of pre-treating the stover in the silo to add value to the feedstock prior to ethanol production.

Leafy and low-lignin varieties are traditionally considered silage hybrids and are typically harvested in early fall. These varieties lodge severely when carried out to full grain harvest, so although they may exhibit good ethanol production traits, they will be a challenge to harvest in late fall. The combine modifications were successful, and a single-pass harvest was achieved. Fractional yield, grain quality and harvesting rate were determined. Particle size of the stover product was too long, which negatively affected the product density in the transport vehicle. Techniques to reduce particle size and to compact the product in the transport vehicle will be a focus in 2005. Pretreatment studies using dilute acids, ammonia, and lime are underway in lab-scale silos.

Harvest Fractionation of Alfalfa

K.J. Shinners*

Funding: Oxbo Corp.

Cooperator: UW Biological Systems Eng.

Since crop cultivation began, grain crops have been harvested by fractionating high-value kernels from low-value stalks. 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- or dry-fractionation, and their use has been limited by many economic and operational difficulties. A major difficulty is that the leaf and stem fractions are harvested as one, and 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 they could be further processed to yield other value-added products. The standing fraction could be cut, wilted, and chopped as high fiber roughage for ruminants, or it 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 the 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. Directly ensiling the leaf fraction was successful when formic acid was used as a preservative or when ground corn grain or dried distillers grains were used as moisture-lowering amendments. The drying rate of the stripped and cut stem fraction was considerably faster than the drying rate of the whole plant. Stems stripped of leaves dried to chopping moisture within two to six hours of leaf removal and cutting. The drying rate was so fast that windrow density may need to be manipulated to manage the window of time the crop is available for ensiling at the correct moisture. Further research will be conducted to improve the systems for direct ensiling of leaf fractions and to estimate the economic viability of alfalfa harvest fractionation.

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 removed from bags were recorded, and samples were 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 56% 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. 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 appeared 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 the top and sides were approximately 40% of densities at the bottom center of the bag.

Losses from a bag were determined after it was emptied. Losses for the 39 emptied bags are tabulated below.

Type of Loss	Range	Average	Average Minus Worst 6 Bags
Invisible plus uncollected	0 to 23	9.2	8.7
Spoilage*	0 to 25	5.4	2.9
Total	0 to 40	14.6	11.6

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

Measurements of DM losses from the 39 bag silos made in both years have been completed, and losses were highly variable (0-40%). However, except for 6 bags with considerable spoilage loss (> 15%), total losses averaged 11.6%. 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 fed out in summer months. 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. Feedout rates are a minimum of 1 ft/d,
4. The best silages (smooth bags made at optimum moisture) are fed in warm weather, and
5. The farmer routinely monitors for and repairs punctures in the bags.

Factors Affecting Bunker Silo Densities

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

Funding: USDA Agric. Research Service; UW Biological Systems Eng.; Agric. and Agri-Food Canada
Cooperators: USDA Dairy Forage Research Ctr.; UW Biological Systems Eng.; 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 were pressure, layer thickness, and kernel processing. Time of compaction within the range studied had little 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.

In 2003, field studies were initiated to confirm the results of the pilot-scale work. One large bunker was filled with alfalfa with packing time on one side being twice that of the other. In another trial, two small bunkers were filled simultaneously with whole-plant corn using different packing tractors. All loads were weighed and sampled for moisture content. The depth of forage in each silo after each load was recorded to estimate the change in density during filling. Finally, as these silos are being emptied, density as a function of depth is being measured through core sampling. More comparisons will be performed in 2005.

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

K.J. Shinners*

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

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 2004, 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 ± 2 percentage unit 81% of the time on the baler. 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 units 71% of the time on the forage harvester. Future research with NIR sensors will focus on improving the diversity of the calibration data set and developing more robust calibrations for in-field estimation of forage moisture.

Wide-Swath Drying: Post Conditioning Systems to Speed Forage Drying

K.J. Shinners*

Funding: John Deere Ottumwa Works
Cooperator: UW Biological Systems Eng.

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. Current research is focused on systems to modify the structure of the windrow at cutting time to improve drying rate. Equipment was developed that merged 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. Basically, a tedder was mounted to the rear of a self-propelled windrower. Windrow hydraulics were used to power the tedder. Its function was quite good, although additional modifications are needed to insure tedding to the full width of the cutting platform. Extensive field evaluation of the system in the first through third cutting was conducted in the summer of 2004. Rainfall was greatly above average so soil moisture was higher than normal for most tests. Despite high soil moisture conditions, tedding at cutting was the most effective treatment to improve drying, followed by tedding on the next day and then conventional treatments. Tedding at cutting produced a 54% increase in the crop's drying rate compared to material that had been similarly conditioned and placed in a windrow. On the first day of drying, the tedded material drying rate was 81% greater than a windrowed treatment. Future work in 2005 will deal with the potential improvement in sugar content of the crop dried in a wide swath prior to chopping and ensiling.

Manure Application Equipment Compaction Study

J.L. Posner*, R.T. Schuler

Funding: UW Agronomy; UW Biological Systems Eng.
Cooperators: UW Agronomy; UW Biological Systems Eng.

Field studies have been initiated to evaluate the impact of manure application equipment on soil properties and crop yield. Studies are being conducted in a privately owned production field and at the UW Agricultural Research Station in Arlington. Corn grain yield and soil cone penetration resistance will be evaluated to determine the impact of soil compaction.

Krusenbaum Dairy Farm Study

J.L. Posner*, R.T. Schuler

Funding: UW Agronomy; UW Biological Systems Eng.
Cooperators: UW Agronomy; UW Biological Systems Eng.

Since 1990 scientists have followed changes and decision-making during the transition on the Krusenbaum Dairy Farm near East Troy, Wisconsin, from a confinement dairy to a rotational grazing dairy and to organic milk production. Field machinery use and cost is being tracked. 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 due to increased grazing.

EXTENSION

Dairy Production

Research and Extension Grants

D.W. Kammel*

As a chair of the modernization work group of the UW-Extension's Dairy Team, I was asked to help coordinate and develop proposals for the Dairy Industry Revitalization Grants as part of a USDA request. I am the primary contact for the following projects.

- Dairy Industry Revitalization Grants USDA:
  Dairy Modernization Website, $17,000;
  Dairy Modernization Construction Cost Database, $14,200;
  Dairy Producer Modernization Survey, $15,000.
- Wisconsin Department of Agriculture, Trade, and Consumer Protection Mixing Loading Pad Design Specification, $8,000.
- Developing Dairy Modernization Planning Teams USDA, $60,800.
- Dairy Modernization Team Training USDA, $12,025.
- Regional Dairy Modernization Workshops USDA, $6,250.
- Odor Control Workshops USDA, $9,775.

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 Eng.; UW Healthy Farmers/Healthy Profits Project; UW Dairy Sci.; UW Ctr. for Dairy Profitability; U. of Minn.; U. of Ill.; 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 they work 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 of providing balanced diets and ample 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, CDs and software to inform farmers and their advisors on farmstead planning, feed storage, feeding, animal housing, milking, 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.

Funding through a USDA-supported project is helping to develop:

- Low Cost Milking Parlor Display;
- Dairy Modernization Website;
- Dairy Modernization Cost of Construction Database;
- Design and Management Options for Low-Cost, Retrofit Milking Parlors.

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 Eng.; USDA Dairy Forage Research Ctr.

Cooperators: UW Coop. Ext. 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 UW Extension's Team Forage website 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 recommended 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, www.uwex.edu/ces/crops/uwforage/storage.htm, for 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 Eng.; UW Dairy Sci.; UW Sch. of Veterinary Med.

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.

Electric Power and Energy Systems

Farm Energy and Stray Voltage Program

D.J. Reinemann*, M.A. Cook, R. Kasper, J. Roberts, D. Hansen
Cooperators: UW Biological Systems Eng.; 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.

Energy Conservation and Renewable Energy Education

P.W. Walsh*, S.G. Gruder
Funding: Wis. Energy Conservation Corp.
Cooperators: UW Coop. Ext. Service; Wis. Focus on Energy; UW Coop. Ext. Solid and Hazardous Waste Educ. 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 statewide clientele regarding adoption of improved energy management techniques, technologies to save and generate energy, and incentives available through Wisconsin Focus on Energy, 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, J.W. Nelson
Funding: UW Coop. Ext. Service; Wis. Farm Technol. Days, Inc.
Cooperators: UW Biological Systems Eng.; UW Soil Sci.; UW Agronomy; UW Dairy Sci.; various county Extension agents

Proper operation, maintenance and selection of agricultural field machinery are the primary focus of the agricultural machinery program. Specific machines and systems receiving the most attention in 2004 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 and impeller conditioners) 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 June of 2004 were wet during late planting and early forage 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 harvesting and machinery operation strategies were recommended as a means of reducing the effects of compaction on crop yield.

Wisconsin's annual Farm Technology Days (FTD) provides an opportunity 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 corn silage and shelled corn. In 2004, other demonstrations were silage bagging, bale processing, and tillage. Corn silage samples were collected and analyzed for particle length. The results were presented to those in attendance.

Environmental Quality

Domestic On-Site Wastewater Management

J.O. Peterson*, J.C. Converse, E.J. Tyler
Funding: UW Coop. Ext. Service
Cooperators: UW Biological Systems Eng.; UW Environ. 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:

- Soil properties and description;
- Soil treatment and dispersal systems;
- Evaluation and maintenance of on-site systems;
- Design of distribution systems;
- Pre-treatment system principles and applications;
- Implications of widespread adoption of uniform code provisions for on-site wastewater management.

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.

Improving Water Quality

B.J. Holmes*, D.W. Kammel, J.O. Peterson, D.J. Reinemann
Funding: UW Coop. Ext. Service
Cooperators: UW Biological Systems Eng.; UW Soil Sci.; UW Environ. Resources Ctr.; 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.

- Proper storage and handling of fertilizers, pesticides, and fuel to minimize losses to water resources.
- Regulations and standards to store and handle manure which are aimed at reducing the amount of manure and nutrients that enter surface and ground water.
- Demonstrations of equipment and management to practice conservation tillage techniques that have proven effective in reducing soil erosion.
- Self-assessment techniques (FarmXAXSyst program) to deter-mine farmstead practices posing high risks to surface and ground water quality.
- A survey of grazier outwintering practices that could affect surface runoff of nutrients.
- Development of an environmental management system (EMS) for dairy farms to reduce environmental risk and increase environmental protection.
- Development of a standard for designing systems to manage milking center wastewater.
- Investigation of environmentally friendly cleaning and sanitizing agents.
- Home water quality testing and interpretation for students in the Farm and Industry Short Course livestock housing class.
- 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.

Safety and Health

AgrAbility of Wisconsin

R.T. Schuler*, C.A. Abplanalp
Funding: USDA CSREES; UW Coop. Ext. Service
Cooperators: UW Biological Systems Eng.; Easter Seals Wis.; Wis. Div. of Vocational Rehabilitation

During its 13 years of activities, AgrAbility of Wisconsin has provided direct assistance to about 1200 disabled farmers and disabled members of their families (www.bse.wisc.edu/agrability). Disabilities addressed include arthritis, cancer, lower back pain, spinal cord injuries, respiratory and cardiac problems, amputations, and visual and hearing impairments.

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 provide on-farm help via worksite assessments and development of individual plans.

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. During the past year, the value of the assistive technology provided by DVR to Wisconsin farmers exceeded $2 million. 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. Members of our staff provide 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, L.N. Adams

Funding: USDA CSREES; UW Coop. Ext. Service; contributions from agri-businesses

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

The 24 state/regional AgrAbility projects are given training and educational support by the National AgrAbility Project staff. The 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 offered through a national workshop, monthly newsletters (distributed electronically only), quarterly technical news and e-mail. The website (www.agrabilityproject.org) was developed and will be further refined to provide information to state project staff and the general public. The website allows access to an assistive technology database listing more than 1000 items. A photo library recently became available to staff of state projects. A National Workshop was held in Springfield, Illinois, 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 serve. An impact survey has been developed to determine how well AgrAbiity meets the needs of farmers with disabilities. These activities have improved the productivity and profitability of those who have been served.

Youth Agricultural Safety and Health

C.A. Skjolaas*, C.C. Wilke, R.T. Schuler

Funding: UW Coop. Ext. Service

Cooperator: UW Biological Systems Eng.

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

R.T. Schuler*, C.A. Skjolaas, C.C. Wilke

Funding: UW Coop. Ext. Service

Cooperator: UW Biological Systems Eng.

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, www.wiscash.uwex.edu. 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*, J.W. Nelson, M. Miller

Funding: UW Coop. Ext. Service; Wis. Rural Insurance

Cooperators: 4-H Youth Development; Natl. Eng., Sci. and Leadership Mgmt. Team; Lincoln Welding; Deere and Co.

In 2004, 40 4-H youth participated in the state mechanical events, which included tractor, small engine, and aerospace. Fifteen county agricultural and youth development Extension agents and county youth development volunteers supported state events. Winners at the state level advance to the National 4-H Engineering, Science, and Leadership Event held each year 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.

Approximately 12,000 youth participate in these Mechanical Science projects at the county level. About 1000 volunteers within the various counties 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.

Future Farmers of America Agricultural Mechanics Events

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

In 2004, 24 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, R.T. Schuler
Funding: UW Coop. Ext. Service
Cooperator: UW Biological Systems Eng.

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

David R, Bohnhoff. President's Citation from the American Society of Agricultural Engineers to recognize his efforts regarding education and his leadership in revising key standards used by the post-frame construction industry.

James C. Converse. Distinguished Service Award from the National Onsite Wastewater and Recycling Association for his work as Chair of the International Symposium on Individual and Small Community Wastewater Treatment Systems and his service as NOWRA's Meetings Council Chair (2002-2004).

James C. Converse. Recognition for outstanding research and education by the Wisconsin Onsite Wastewater Recycling Association.

Sundaram Gunasekaran. Appointed Honorary Visiting Professor, Zhongkai University, Guangzhou, China, 2004-2007.

Jeffrey W. Nelson and Ronald T. Schuler. Received the Donald R. Peterson Farm Technology Transfer Award to recognize their exhibit at the 2004 Wisconsin Farm Technology Days. Professor Schuler's efforts for Farm Technology Days spans 21 years. He continues to recruit industry representatives for and organizes field demonstrations of many varieties of farm equipment at this annual event.

Ronald T. Schuler. Inducted as a Fellow of the American Society of Agricultural Engineers in recognition of his contributions to academics through classroom instruction, research, administration, and extension/outreach, and for his service to the Society.

Students

Graham S. Adsit. 2004 Student Honor Award from the American Society of Agricultural Engineering for scholarship and participation in student club and campus activities during his undergraduate studies (President of the student club for 2002-2003 and Co-leader of the Quarter Scale Tractor Team for 2003-2004).

Josiah B. Akin. 2004 Outstanding Undergraduate Student Award from the Wisconsin Section of the American Society of Agricultural Engineering. He served as Vice-President of Wisconsin's student branch, is a leader of the Quarter-Scale Tractor Team, and served on the Student Council of the UW College of Agricultural and Life Sciences.

Aaron R. Flouro. Elected Secretary of the National Council of Student Clubs of the American Society of Agricultural Engineers.

Pre-professional Student Club. Again received First Place Trophy in the Group B (fewer than 35 members) Competition of the Association of Equipment Manufacturers for its accomplishments during the 2003-04 school year. The award is based on the quality of club meetings, the club's activities, and individual student's activities.

Quarter-scale Tractor Team. Placed 16th among 25 teams participating in the ASAE-sponsored competition. Competition consists of a written design report , team presentation, tractor design (16th place), performance/pulling (11th place), and maneuverability. The team was awarded second place for the separate web design competition.

Quarter-scale Tractor X-Team (for younger undergraduates). Placed 8th among 12 teams. This competition, also sponsored by ASAE, consists of performance/pulling, written report (6th place), and oral presentation (3rd place).

Anthony J. Vandermuss. 2004 Outstanding Graduate Student Award from the Wisconsin Section of the American Society of Agricultural Engineering. He is active in Wisconsin's student branch, serving as one of the authors of the winning report (see directly above) submitted to the Association of Equipment Manufacturers.

Publications

Peer Reviewed Publications

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