PURDUE UNIVERSITY

U.S.-CHINA ECOPARTNERSHIP FOR ENVIRONMENTAL SUSTAINABILITY

Purdue Resource Series

Environmental Sciences and Engineering

节能环保产业

- **High-efficiency and energy saving** 高效和节能
- **Advanced Environmental Protection**
  先进环保技术
- **Recycling Usage** 回收利用
- **Reusing Waste Products** 废物再利用

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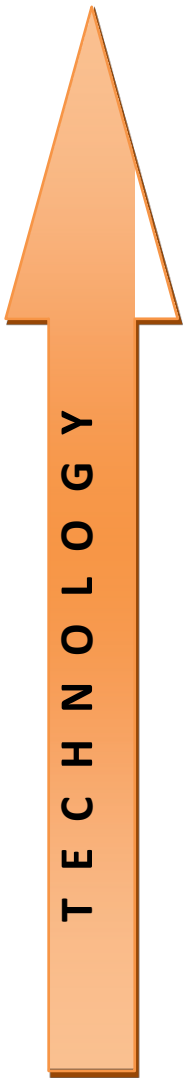
Section 1: Technologies

The following Purdue technologies are available for potential development, licensing or commercialization. Many of the technologies include a Technology Readiness Level (TRL) number which indicates how close each technology is to the market. The following chart describes these categories.

Definition of Technology Readiness Levels (source: NASA)



Applied	**TRL 9**	**Actual system "mission proven" through successful mission operations** Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.
	TRL 8	**Actual system completed and "mission qualified" through test and demonstration in an operational environment:** End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios.
	TRL 7	**System prototyping demonstration in an operational environment** System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.
	TRL 6	**System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space):** Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
Advanced	**TRL 5**	**System/subsystem/component validation in relevant environment:** Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
	TRL 4	**Component/subsystem validation in laboratory environment:** Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.
Basic	**TRL 3**	**Analytical and experimental critical function and/or characteristic proof-of concept:** Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies.
	TRL 2	**Technology concept and/or application formulated:** Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.
	TRL 1	**Basic principles observed and reported:** Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.

PRF No. 65981 Enzymatic Treatment of Alginate to Reduce Membrane Fouling for Municipal Wastewater Reuse

Population growth and economic development are placing increasing demands on limited fresh water resources worldwide. When natural water resources are not enough to meet the requirements of water supply, it is necessary to reuse treated wastewater. Wastewater reuse has proven to be effective and successful in creating a new and a reliable water supply. This is a sustainable approach and can be cost–effective in the long term. In order to meet the quality requirement for wastewater reuse, advanced treatment technologies are necessary.

Membrane filtration technologies have been widely used in desalination and advanced water and wastewater treatment practices. Wider application of the membrane technologies is driven by increasingly stringent regulations for finished water quality. Therefore, multiple membrane processes are regarded as key elements of advanced wastewater reclamation and reuse schemes. However, one of the main barriers to greater use of the membrane technologies is membrane fouling, which is caused by deposition and/or adsorption of water impurities such as organic substances and particulates, on the membrane surface and/or pores. As a result, the productivity of the membranes declines significantly with filtration time. Membrane fouling affects both the quality and the quantity of the product water and ultimately shortens the membrane life, if the fouling is irreversible. It is reported that membrane replacement due to fouling is the single largest operating cost.

Researchers at Purdue University have developed a method to efficiently clean membranes used in wastewater filtration. This technique employs an enzyme to break down the organic buildup on the membranes instead of a chemical-based cleaner. This increases membrane productivity and effective life as a result of decreased clogging.

Wastewater treatment facilities will generate revenues of $41.6 billion in 2011 at an annual growth rate of 1.8% according to market research done by IBISWorld. Growth has been driven by economic recovery, which causes consumers and businesses alike to create more waste.

Advantages:

- Improves membrane performance by reducing clogging and extending membrane life
- Applicable to reverse osmosis, nanofiltration, ultrafiltration, and microfiltration membranes

PRF No. 65677 Nonlinear, Bifurcation-Based Mass Sensor

Technology Readiness Level: 3

Sensors that detect chemical and biological agents are of increasing importance in medical diagnostics, environmental safety, and national security as well as a range of other fields. Microscale resonator based sensors are the current industry standard for these applications because of their high sensitivity and small footprint. By detecting the frequency shift when a gas or chemical molecule lands on the sensor they are able to detect and identify even minute traces of the compound.

Purdue researchers have developed a new mass sensing technique that can be applied to microscale resonant sensors for detecting chemical and biological agents. Instead of measuring the linear frequency shift, the new technique detects a nonlinear change in the frequency response of the resonator. This approach could increase the sensitivity of chemical sensors and eliminates the need for power-consuming, frequency-tracking components in the sensor array.

Advantages:

- Monitors a nonlinear response
- Reduced power consumption
- Improved sensitivity

PRF No. 64699 Self-Cleaning Anti-Fogging Materials

Technology Readiness Level: 8

It has been possible to separate small amounts of oil from water for quite some time. This was made possible through the use of nanoporous filters. Unfortunately, the minute size of the holes in a nanoporous filter requires the filtering process to be highly pressurized in order to function. In some situations, such as oil spill cleanup, this is not always practical. Purdue University researchers have devised a method of separating the small amounts of oil from water through the use of an advanced membrane coated glass micro filter. Micro filters don't have the same pressure requirements as nanoporous filters; therefore, water can flow freely through them. The membrane is composed of a patented hydrophilic layer of polyethylene glycol and each molecule is tipped with fluorine. The water is attracted by the polyethylene glycol flowing through both layers freely, and the oil is stopped at the fluorine barrier where it beads and can be easily removed through the use of cross flow filtration. Typical filters collect oil and must be changed out frequently when they have been rendered ineffective. This technology saves money by extending the life of the filter and making the oil easy to remove instead of exchanging the filter. This is done without the need for high pressure parts, thereby lowering system costs.

Advantages:

- High Pressure system is not necessary
- Longer life so filters do not need to be replaced as often

PRF No. 64581 Window That Improves Air Quality and Energy Use

Technology Readiness Level: 5

It has been reported that up to 90 percent of a typical American's time is spent indoors. Poor air quality often present indoors has been linked to respiratory illness, allergies, asthma, and sick building syndrome. Additionally, buildings in the United States account for one-third of the total primary energy consumption and two-thirds of the electricity consumption. Current window technology is limited in its ability to offer Improvement of Air Quality (IAQ). Windows that allow air flow within current airflow designs are inefficient and are constrained to a single air flow path.

Purdue University researchers have developed a more efficient window that improves air quality and conserves energy, exhausting the lesser quality air in a room and flowing in fresh, outdoor air by its two-way flow path. The air that flows into a room is appropriately tempered to conserve energy for heating or cooling a room throughout the year. On a calm, sunny day in the winter, tests have concluded that outdoor air can be preheated by up to 18Â°C (80 percent efficiency). Similarly, on a calm, cloudy day in the summer, outdoor air can be precooled by up to 3Â°C (24 percent efficiency).

Advantages:

- A more efficient window
- Improved air quality

PRF No. 64495 Robust RF Antenna for Sewage Monitoring

Technology Readiness Level: 8

Sewer lines require constant monitoring in order to track sewage content. Currently, sewage monitoring is carried out by individuals who manually sample sewer lines with specialized equipment or by equipment permanently housed in water treatment facilities.

These current solutions are neither cost effective nor mobile enough to accurately monitor the content of an entire city's sewer system. Introduction of a wireless sensor system to monitor sewage content would remove the cost of manual measurement and be expansive enough to accurately cover a citywide system; however, for a wireless system to work efficiently, the sensor antenna would have to be located above the sewer at ground level in order to minimize signal interference.

Researchers at Purdue University have developed a method of manufacturing an adaptive radio frequency antenna into an existing or manufactured manhole cover. This places the antenna at ground level, reducing transmission interference. The integrated antenna provides a low-cost method of wirelessly transmitting water quality information from a remote site to a base station for data collection and analysis.

Advantages:

- Low cost
- Utilizes existing manhole covers
- Does not require roadway construction

PRF No. 65931 Enzymatic Treatment of Municipal Wastewater

Technology Readiness Level: 4

Water shortage problems have been addressed by increasing wastewater reuse. Wastewater reuse has proven effective for water conservation; however, there are strict safety and quality requirements that must be met. This requires the use of advanced treatment technologies such as membrane filtration. Currently, microorganisms in wastewater secrete polysaccharides which deposit in the pores of the membrane, which requires the membrane to be cleaned or replaced. Cleaning or replacing the membranes is expensive. Cleaning can also damage the membrane, and it is not very effective for tightly adhered contaminants such as polysaccharides.

Purdue University researchers have developed a method for cleaning the membranes. This process uses an enzyme to degrade the polysaccharides that have built up on the membrane. This method is cost effective by eliminating the need for expensive chemical cleaners or membrane replacement.

Advantages:

- Improves membrane performance by reducing clogging and extending membrane life
- Applicable to reverse osmosis, nanofiltration, ultrafiltration, and microfiltration membranes

PRF No. 65894 Chitosan Derivative for Endotoxin Inactivation

Technology Readiness Level: 3

Septicemia refers to the presence of pathogens in the bloodstream that leads to sepsis, a potentially life-threatening medical condition characterized by whole-body inflammation and the presence of infection. When microbes infect the blood, skin, lungs or other tissues, the body's immune system generates an inflammatory response in attempt to fight the infection. The body's immune response to the infection causes the characteristic symptoms of sepsis and can lead to organ failure. Current treatments for sepsis require antibiotics, fluid drainage, blood transfusions, and dialysis. Since individual cases are caused by different microbes, the correct antibiotic must be chosen to treat the infection. This causes a delay in treatment which leads to an increase in the mortality rate.

Purdue University researchers have developed a novel treatment for septicemia involving molecules derived from chitosan. Chitosan is a linear carbohydrate with many commercial and biomedical uses. This treatment inactivates endotoxins which are toxins associated with certain types of bacteria and which stimulate cytokine release (part of the body's inflammatory response that causes swelling and high fever). This new chitosan shows many advantages over current IV treatments for septicemia. This technology can also be used to filter endotoxins out of plasmid DNA samples, and filter bacteria from water, making contaminated water samples safe to drink.

Domain:

- Biomedical
- Green Technologies

Advantages:

- Stronger affinity for inactivating endotoxins
- Excellent biocampatability upon injection
- Lower potential to cause hemolysis, complement activation, and inflammatory responses
- Can filter endotoxins out of plasmid DNA samples
- Can remove bacteria from water

PRF No. 65920 Continuous-flow Solar Ultraviolet Disinfection System for Drinking Water

Technology Readiness Level: 5

A major health concern in developing countries around the world is water quality. Water can be contaminated with disease-causing pathogens or with harmful chemicals. Technologies used in developed countries are often not practical for developing nations due to cost and energy requirements. Solar UV radiation inactivates pathogens in a water supply by causing damage to nucleic acids and proteins so that the cell cannot replicate and cause an infection. The empirical design of current technologies still leaves uncertainty about the quality of the disinfected water. In addition, existing disinfection systems that use a constant-flow design require electrical energy to generate artificial UV radiation, which is not practical for developing nations.

Researchers at Purdue University have developed a solar UV radiation based system to disinfect water continuously. Water is pumped through a UV-transparent tube that is positioned in a solar concentrator. Controlled flow of water through the irradiated area allows for reliable and predictable performance.

Domain:

- Civil/Chemical Engineering
- Chemical Engineering
- Food and Nutrition
- Green Technologies

Advantages:

- More reliable and predictable decontamination
- No power required
- Inexpensive and facile

PRF No. 65818 Fabrication Technique for Oxazine-Based Opto-Chemical Sensor for Detection of Contaminants in Water

Technology Readiness Level: 5

Ammonia at elevated concentrations is poisonous to different organisms. For examples, 22.8 ppm can be lethal to water organisms and exposure to ammonia as low as 35 ppm for over 15 minutes can be dangerous to human beings. Therefore, a continuous online ammonia monitoring system is highly desired, especially for dynamic aqueous water delivery systems.

While various technologies have been studied for the detection of ammonia, sensors such as electro-chemical gas sensors, catalytic sensors, chemi-resistor sensors, CHEMFET sensors, and optical fiber sensors have attracted substantial attentions for the monitoring of ammonia in gaseous phase as they provide easy and fast means of continuous detection. The majority of the optical fiber ammonia sensor research efforts have been focused on the employment of Glass Optical Fiber (GOF). As of yet, very little work on the development of Plastic Optical Fiber (POF) sensors for ammonia detection have been reported and the GOF sensors have primarily focused on the detection of ammonia in the gaseous phase (such as in air), only few had been deployed in aqueous media. However, POF is much more flexible and mechanically much stronger than the GOF and POF is a more suitable choice when applications such as monitoring ammonia in the artificial water delivery systems (which requires the usage of very long optical fibers) are concerned.

Domain:

- Mechanical Engineering

Advantages:

- Good reversibility
- Compact
- Lightweight
- Relatively inexpensive
- Immune to electromagnetic interference

PRF No. 62066 Microsensor Arrays for Bacterial Detection

Concerns about biological warfare have peaked interest in sensitive detection of microorganisms such as viruses and bacteria. One method for detection of bacteria is to use the naturally occurring antibody-antigen chemistry to trap the bacteria onto a patterned substrate. Patterning the antibody into a microarray helps facilitate detection through a multitude of possible pattern recognition algorithms.

Purdue researchers have developed a new method for multi-threat bacterial detection that is rapid, economical, and offers the potential for mass production. They have extended the micro array concept from the field of proteomics to bio-hazard detection. This method incorporates an immunological assay platform capable of reagent free, real-time antibody based detection of a wide variety of aqueous-borne bio-contaminants. The immunological complex formation can be sensed directly using an array of sub-micron sensing elements, thereby permitting multiple-threat detection capabilities. It is anticipated that upon insertion of a bio-chip into a hand-held device, a positive identification of biohazard will occur in real time.

Domain:

- Biotechnology

Advantages:

- Multiple-threat detection capability
- Positive biohazard idenitification in real time

PRF No. 62093 Enhanced Raman Protein Sensing Technologies

Protein detection and sensing is currently done with chromatographic, electrophoretic, and mass spectroscopic technologies. Unfortunately these techniques are expensive, inefficient, and are unable to detect important parameters such as protein phosphorylation, glycoprotein branching, conformation, and drug binding.

Purdue University researchers have developed a novel technique for multiplexed protein analysis with enhanced sensitivity and a lower recurring chemical cost when compared to current proteomic detection and labeling technologies. This invention combines state-of-the-art signal enhancement, optical detection, and data processing techniques to produce a new family of optical sensors. These can be used for proteomic detection, screening, analysis, and drug discovery. The proposed sensors will facilitate the measurement of changes in protein structure and composition, which would be difficult or impossible to detect using chromatographic, electrophoretic, or even mass spectroscopic proteomic sensing methods alone. This technology can be used as a highly sensitive stand-alone protein sensor (down to a single protein level) capable of identifying chemical and structural information (to detect protein post-translation modifications, conformational changes, and binding events). Alternatively, this technology could be integrated into chromatographic, electrophoretic, and mass-spectroscopic protein separation and storage instrument, which would provide enhanced protein detection, identification, and modification sensing functionality.

Domain:

- Biotechnology

Advantages:

- High throughput capabilities
- Enhanced sensitivity to detect
- Stand-alone integrated system

Section 2: Companies in Purdue's Research Park that may be interested in international collaboration

For more information on Research Park and its companies, see http://purdueresearchpark.com/

Algaeon, Inc.
www.algaeon-inc.com/

Conservation Technology Information Center (CTIC)
www.conservationinformation.org

En'Urga, Inc.
www.enurga.com/

Exhale Fans, LLC
exhalefans.com/

Green Tech America, Inc.
www.greentechamerica.com

Indiana Technology Group, LLC
indianatechnologygroup.com/

Legacy Environmental Services, Inc.
www.legacyenv.com/

WindStream Technologies
www.windstream-inc.com/