Algal Technology Laboratory

Cultivating *Spirulina platensis* for high-value chemicals

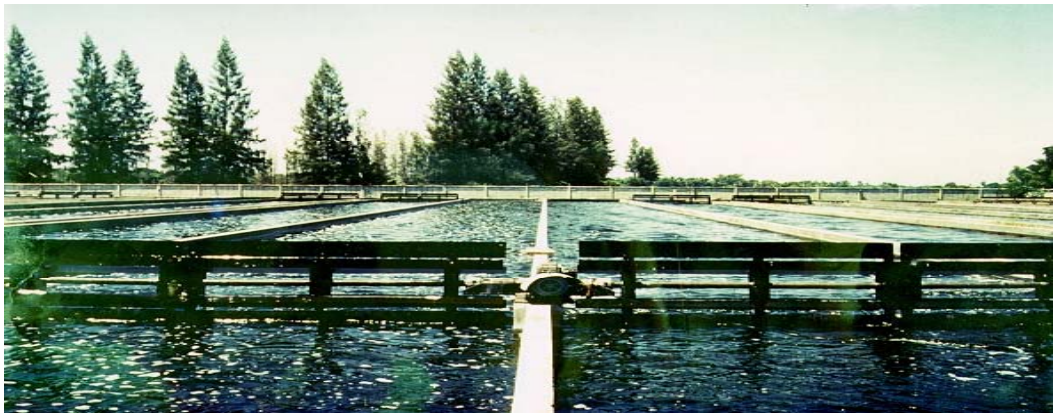
Asst.Prof.Bussaya Bunnag
Lab Director
E-mail: busya.bun@.kmutt.ac.th

In recent years, microalgae have gained much attention due to their high nutritional value, high-value chemicals (pigments and vitamins), high growth rate as compared to higher plants, and the ability to utilize light energy. In addition, many bioactive compounds have been found in microalgae. For example, dried microalgae could be used as high-protein feeds for animals such as shrimp and fish. Since Thailand possesses a varied topographical nature and a typically tropical climate, the country is ideal for cultivating and growing algae. For this reason, mass cultivation of microalgae in Thailand has a high potential both for local consumption and for export.

The Algal Technology Lab at KMUTT has been at the forefront of algal technology. The Lab emphasizes research on developing mass cultivation techniques and extraction processes in order to obtain value-added compounds such as phycocyanin and gamma-linolenic acid (GLA). One of the goals is to enhance cell growth and maximize the production of value-added chemicals in *Spirulina platensis***.** In the past one year, the Algal Lab has been very active in trying to find the right substrate and environmental conditions for cultivating different strains of *Spirulina platensis.* For example, it was found that CO_2 could be used to replace $NaHCO_3$ in cultivating microalgae with substantial lower production costs. Moreover, effect of light and temperature on the productivity and photosynthesis of the algae in an outdoor environment were investigate. In addition other research focuses on trying to understand the mechanism by which *Spirulina* produces value-added compounds such as phycocyanin and GLA so that new strains with higher contents of such compounds can be developed. Different approaches were studied, including mutagenesis using EMS (Ethyl Methane Sulfonate) as a mutagen, the use of inhibitors, and the use of inducers/enhancers such as herbs.

One of the most important factors affecting the productivity of the algae is the design of ponds or reactors. High growth rate algal ponds which are commonly utililized in cultivation of microalgae have not been fully developed to obtain maximum productivity. The Lab was able to develop a mathematical model for *Spirulina* production which led to an effective design in a tubular photobioreactor.

Future works in this field include the study of the production of polysaccharide and further investigations into mutagenesis in *Spirulina.*



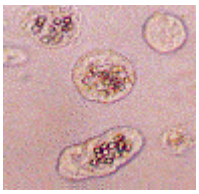
Spirulina Production Technology Development Transferred to a Local Entrepreneur.

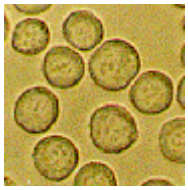
Animal Cell Culture Laboratory

Dr.Phenchan Mekvichitsaeng
Lab Director
E-mail: Phenchan@pdti.kmutt.ac.th

Animal Cell Culture Group was established to conduct researches involving the use of animal cells (especially insect cells) as a factory for the production of high value bioactive products such as recombinant proteins (in which the modifications of recombinant proteins by higher eukaryotes is needed), viruses, etc. Insect cellcultures are initially used by our group both in small scale (100-200 ml) and large-scale (20 L) culture. Our main products that are currently being produced from the insect cells are wild type baculovirus (e.g. Helicoverpa armigera NPV, HaNPV) and recombinant dengue viral proteins.

Wild type baculovirus





Baculovirus is a well known biopesticide by its characteristics of host specificity, environmental friendly and human (and animal/plant) safety.The department of agriculture is now encouraging Thai farmers to use the biopesticide as alternatives for chemical insecticides. The demand for this baculovirus is therefore increasing. We have sucessfully isolated a Thai HaNPV baculovirus from infected cotton ball worms (Helicoverpa armigera) and propagated these viruses in a Hz insect cell line. Large-scale production of this local Thai isolated HaNPV baculovirus in bioreactors (2.5 L and 20 L) is now under investigation in our laboratory. Many more species of local baculovirus which can be used for control of other pest species will also be isolated and produced in insect cell culture in the future.

Recombinant proteins

Recombinant proteins produced from animal cells is also one of our targets especially those that can be used as vaccines or as a part of diagnostic kits. Baculovirus Expression Insect Cell System has been used as a tool for the expression of heterologous genes in insect cells which results in recombinant protein production. A number of genes such as dengue viral envelop (E) and non-structure 1 (NS1) genes have been successfully expressed. With the experience gained from these gene expressions, many more genes expressed by this system can be achieved. Larger scale production of recombinant protein from insect cell culture is also one of our main objectives for the further duel - xxxx in moving towards industrial scale production.

Contact Person: Dr. Kanokwan Poomputsa Email: kanokwan.poo@kmutt.ac.th

Biohydrometallurgy

Recovery of value metals from waste

Dr. Paithip Theeravetyan
Lab Director
E-mail : Paithip. The @.kmutt.ac.th

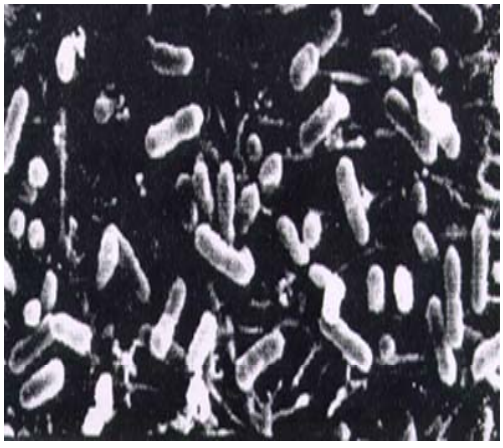
The Biohydromettalurgy Laboratory is focussed on recovery of values metals from industrial waste product, soil, sediment and waste water sludge. The lab also conducts. Studies on fundamental, mechanism and application in the mining industry.

At present, this laboratory is active in the falling research auras:

- Recovery of copper from low-grade copper sulphide ores by biohydrometallurgy
- Modelling of bioleaching of copper from low-grade copper sulphide ores
- Bioleaching of zine from mining waste
- Mechanism of extraction of zinc from mining waste by *T. ferrooxidans*
- Entrapment of gold by rice-hull ash

Bioleaching of copper from low-grade copper sulphide ores by Thiobacillus ferrooxidans in a column leaching

Thiobacillus ferrooxidans has been used in Copper mining



Combustion Technology Laboratory

New systems for cleaner environments

Assoc. Prof. Dr. Suvit Tia
Lab Director
E-mail: suvit.tia@ kmutt.ac.th

As Thailand becomes more industrialized, there is a growing concern the environmental impact from industrialization, particularly pollution resulting from fuel combustions. The Combustion Technology Laboratory at KMUTT aims to improve methods of combustion for different fuel sources in order to improve the efficiency, thus leading to cleaner environments.

The Lab is currently active in studying coal and biomass combustion as well as in situ desulfurization using natural limestone and combustor. Other research works such as the improvement of LPG cooking stove, catalytic combustion of soot from diesel engine and combustion of low heating value gaseous fuel in a crater bed have also been studied.

Fluidized bed Boiler for Superheated Steam Production
(5 tons/hr at 30 barg, 350^{o}C)
Ampol Food Processing Co., Ltd

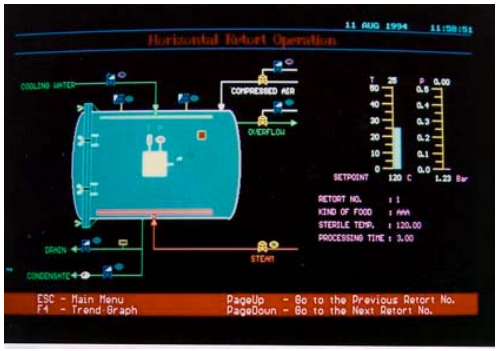
Application of Swirl Burner
for LPG Cooker

Computer Applications and Development Laboratory

Computer technology for chemical process industry

The Computer Applications Lab is primarily involved in the development and application of the latest state-of-the-art computer technologies for application in the chemical process industry. To date, one of the most successful applications has been the development of a retort system, trademarked **RetortOp, designed for management/supervision and control of retort lines in food processing industries**. The system was first developed in 1992 with funding from the National Electronics and Computer Technology Center (NECTEC). A pilot-scale demonstration unit is available at KMUTT, and a full-scale working unit has been installed at a factory in Chiang Rai in Northern Thailand. The installation, commissioning, and maintainence of the system are fully supported by the highly professional PDTI staff.

The RetortOp system is easy to use and is especially suited to multi-product operations. With this system, performance of the retort operation is enhanced and human errors created by manual operation are reduced. The system comes in two parts: data acquisition and control software, and the interface hardware. One computer can to control a large number of retorts simultaneously. The data sampling rate can easily be set from the menu to different speeds. Real-time display is available to the supervisor in graphic mode and may also be permanently stored in user-defined files.



RetortOp is loaded with the following features :

- ❖ User-friendly, menu-driven function blocks with pull-down menu and pop-up windows.
- ❖ Real-time animation of process flow diagrams.

Retort Operation System at
Royal Project Plant (Maechan)

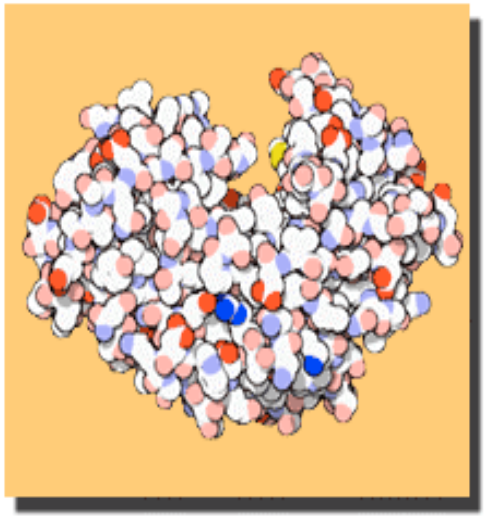
- ❖ On-line, real-time data acquistion and monitoring.
- ❖ Man-machine interfaces are in both text and graphics mode.
- ❖ Graphical data display gives very convenient analysis.
- ❖ Acquired data can be readily transformed into Lotus or Excel format for further manipulation.
- ❖ Simultaneous control of up to 8 retorts.
- ❖ Operation can be set for either automatic sequential control by computer or manual control by operator and control panels.
- ❖ Automatic compensation of cooking/processing time in situations where sterilization is insufficient.

Contact Person: Mr. Worasit Ratanboonkorn Email: Worasit @pdti.kmutt.ac.th

Enzyme Technology Laboratory

Assoc. Prof. Dr. Khanok RatanaKhanokchai
Lab Director
E-mail : Khanok.Rat@ Kmutt.ac.th

As enzyme Technology is the one of the most important field in biotechnology, increasingly enzymes and their applications can be found in many industrial processes.To study the selection of microorganisms, production, purification, modification of hydrolytic enzymes and their applications ***are the purpose in our Enzyme Technology Laboratory.*** The research activities of the laboratory deal with two main studies: the first one is the study on the hydrolytic enzyme systems of industrial interest. It includes production of alkaline amylase, cellulase-free xylanases and mannanase from the alkaliphilic *Bacillus firmus* K-1 and *Bacillus* sp. C-1. All these enzymes consist of substrate-binding domains so that they are potentials potently useful for application in detergent and biobleaching of pulp and paper. The rapid purification procedure for the effective production of high purity enzymes has also been conducted in our laboratory, such as xylan-binding endoxy lanase from *Bacillus firmus* K-1 and cellulosome-type multienzyme complex from *Bacteroides* sp. P-1. Modification of cellulase-free alkaline xylanase by chemical method is being carried out for thermostability. After that, this enzyme can be use in prebleaching of pulp and paper process because of its substrate-binding ability, lack of cellulase and thermostability.



The second study is biotechnological upgrading of low value carbon sources for the production of higher value products. It refers to the study on production of multienzyme complex or cellulosome or xylanosome from aerobic bacteria to improve the biodegradation of agricultural wastes. The multienzyme complex is responsible for the efficient breakdown of insoluble cellulosic substances into simple sugars. When breaking down cellulose substrates, many anaerobic bacteria use their cellulosome that composed of numerous, different proteins (many of which are enzymes). In our laboratory, the cellulosome has been discovered and purified from anaerobic bacterium *Bacteroides* sp. P-1. However, currently, cellulosome from aerobic bacteria and xylanosome have not been discovered. Thus, our research group in enzyme laboratory is interested and carries out to study on the production of cellulosome or xylanosome produced by aerobic bacteria. The finding will improve the enzymatic degradation of insoluble agricultural substances to soluble saccharides, which can be converted to valuable products. Moreover, the selection of purified enzyme subunits of cellulosome containing cellulose-binding domains and/or xylan-binding domains for preparation of affinity tags is another emphasis in our laboratory as well.

Fermentation Technology Laboratory

Cultivating bio-products from microorganisms

Asst.Prof.Dr.Yuwapin Dandusitapunth
Lab Director
E-mail: Yuwapin.Dan@ kmutt.ac.th

The Fermentation Lab is involved in the research and development of fermentation techniques and cultivation of bio-products from microorganisms such as yeast, bacteria, fungi, and virus. To date, the Lab has successfully developed a technology in the pilot plant at PDTI for the production of one ton of dry - weight baker's yeast (*Saccharomyces cerevisiae)* per month. The baker's yeast produced has been successfully used to produce bakery products, such as bread, which have excellent aroma and flavor. The baker's yeast produced is a natural, local strain. The strain has been proven to be genetically stable, giving reproducible fermentation performance and subsequent baking properties. This technology has been clearly proven at laboratory and pilot scale, both from microbiological and engineering perspectives. Hence, the technology is ready for commercialization.

The Fermentation Lab has been very active in many research fronts. One study focuses on investigating the strategy for maximizing the trehalose production in *Saccharomyces cerevisiae* by fed-batch fermentation under laboratory conditions.
Trehalose is often used as preservatives, additives, and moisturizer in cosmestics. If successful, the data from the study will be used to build and test a pilot-scale process which should eventually lead to commercial-scale production. Another study centers around the effect of temperature in the range of 10-30^{o}C on fatty acid profiles (e.g.gamma linolenic acid) and growth in a fungus called *Mucor rouxii*. This leads to better understanding of the mechanism of fatty acid production in fungus. Gamma linolenic acid is an important ingredient in health foods, which currently enjoys a huge worldwide market.

Recently, a class of fungi has been found to be capable of producing chemicals that are effective against the spread of the HIV virus, the virus that causes AIDS. *Cordyceps pseudomilitaris,* an insect pathogenic fungus, is a representative of this class of fungi. The Lab has in the past few months tried to cultivate and characterize this fungus. Needless to say, this research has immense potentials in terms of medical benefits.

1,500 Litre Fermentor in
PDTI 's Pilot Plant

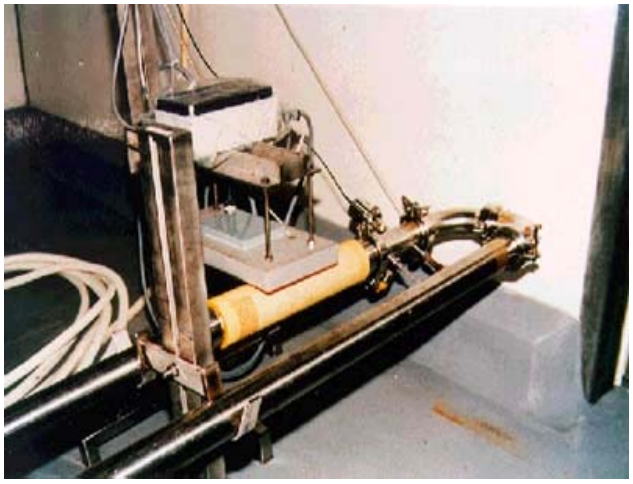
Food Technology and Engineering Laboratory

Thermal processing Technology

Asst.Prof.Dr.Tipaporn Yoovidchaya
Lab Director
E-mail: .Tipaporn Yoo @kmutt.ac.th

Thermal processing plays major role in food processing in Thailand since it is the core technology employed in the food industry. Increasingly, consumer's demand for nutritious, shelf-stable and easy-to-prepare food, gradually changes the trend towards application of less heat treatment. Application of aseptic processing to particulate food product is a good example: with the use of high temperature short-time process, nutrition loss is reduced, therefore the quality of food products increases. The development of ohmic heating to food product is another example. This can provide an alternative method for sterilization of food and result in higher quality food product.

Food Technology and Engineering Research Lab at KMUTT has conducted a number of studies on thermal diffusivity, aiming to develop predictive equations for determining sterilizing values of Thai food products in various can sizes. The research work involving applications of aseptic processing to particulate food products has also been carried out with the aim of developing electronic identification techniques to determine particle residence time in a continuous bioprocessing system. Local technology using ohmic heating for sterilization of food products has also been developed. In the area of dehydration, most of the research work being carried out at the Lab emphasizes the design and control of drying process to obtain desired quality products.



Electronic Identification Device

Transponder in Food Process

Membrane Technology Laboratory

The membrane research group at KMUTT brings together membrane research activities from the Department of Chemical Engineering (Faculty of Engineering), Division of Biochemical Technology (School of Bioresources and Technology) and Pilot Plant Development & Training Institute. The strength and uniqueness of the group lies in this collaborative, interdisciplinary approach that covers the full range of activities from the preparation of synthetic membranes to a variety of applications and the transport phenomena of the membrane processes. Our current activities involve:

Fundamentals of membrane transport mechanism and fouling

- Transport models for pervaporation of aqueous organic solutions
- The effects of Acid treatment of UF ceramic membrane on protein adsorption
- Pretreatment of UF polymeric membranes by surfactants for reduction of protein fouling
- Sorption and diffusion of organic vapors by membranes
- Facilitated transport in gas permeation

Application of membrane processes

Application of ultrafiltration, microfiltration and preparation to separate various feed solutions is studied. For example:

- Alcohol-water mixture separation by pervaporation
- Ultrafiltration of pineapple/passion fruit juice
- Separation of oil from wastewater by ultrafiltration
- Treatment of effluent from fish canning industry by ultrafiltration
- Recovery of aroma from fruit juice by pervaporation
- Production of *S.cerevesiae* in stirred ceramic membrane reactor
- Membrane processes for *testament* of textile effluents

Preparation of synthetic membrane

- Novel hydrophilic PV membranes (Chitosan/ hydroxyethylecllulose blend) for the removal of water from alcohol-water solution.
- Development of hydrophobic PV membranes (silicone membrane filled with silicalite) for the removal of aroma compounds and other low MW organics from aqueous solutions.
- The preparation of ceramic ultrafiltration/microfiltration membranes.

Ceramic
Membrane
Ultrafiltration

Molecular Biology and Gene Technology Laboratory

Biotechnology in algae, fungi, yeasts, and viruses

Asst.Prof.Dr.Supapon Cheevadhanark
Deputy Director, Lab Director
E-mail : Supapon Che@0kmutt.ac.th

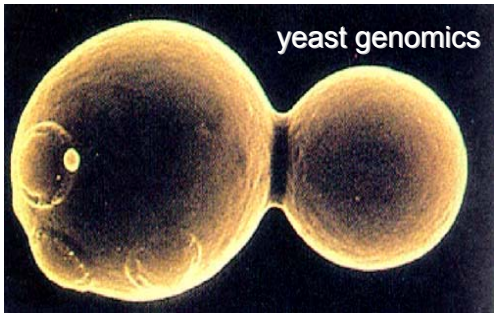
Rapid scientific progress has recently been made in the field of genes and biotechnology. Gene Technology Lab at KMUTT is at the forefront of this cutting-edge technology. The main thrust of the Lab is to develop new techniques in gene technology that can be used to study algae such as *Spirulina platensis*, fungi such as *Mucor rouxii* and *Aspergillus oryzae*, yeasts such as *Saccharomyces cerevisiae*, and viruses such as those causing Dengue fever. Algae, fungi, yeasts, and viruses are important sources of high-value chemicals such as γ-linolenic acid and recombinant proteins. The goals of the Lab are to characterize these biological subjects through gene technology in order to better understand the mechanisms in which these chemicals are produced and to study how these subjects can be extracted more efficiently.

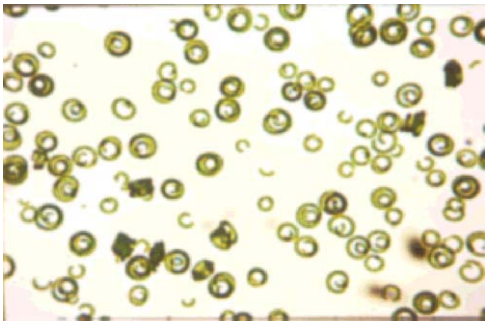
Past research includes:

- Cloning and sequencing of a phycocyanin gene and allophycocyanin gene from *Spirulina platensis* C_1. The DNA sequences of these genes have already been submitted and deposited to Genbank.
- Cloning and sequencing of a Δ9 desaturase gene from *Mucor rouxii* ATCC 24905 and *Spirulina platensis* C_1. The DNA sequences of these genes have also been submitted and deposited to Genbank.
- Fermentation of a genetically engineered *Aspergillus oryzae* U1521.
- A genetic study of the phycocyanin biosynthesis in *Spirulina platensis* C_1.

There are several projects currently being undertaken which are funded by various agencies such as National Center for Genetic Engineering and Biotechnology (BIOTEC) and US Agency for International Development (USAID). Selected projects are:

- Genetic study of the γ-linolenic acid biosynthesis in *Mucor rouxii* ATCC 24905. This is a research aimed at the cloning and the characterization of Δ9 and Δ12 desaturases genes, which are genes involved in the production of γ-linolenic acid.
- Expression of a Dengue viral coat protein in *Aspergillus oryzae* and characterization of its products in *Saccharomyces cerevisiae*.
- Genetic study of fatty acid desaturation in cyanobacterium *Spirulina platensis* C_1, which involves the temperature regulation of desaturase gene expression.





Process and Environmental Analysis Center

The Process and Environmental Analysis Center was established in 1994 to provide services in chemical, physical, microbiological analyses to the various research centers at PDTI and within KMUTT, as well as to outside companies and organizations. Since then, the Lab has performed thousands of analyses on numerous parameters for many different industries. Examples of applications are water and waste water analysis from the tapioca starch, fermentation, food, and agricultural industries. The analyses can be performed either in-house or on-site. But wherever it is, the analyses are always carried out in the most efficient, accurate, and reliable manner, using standard methods that are internationally approved.

In addition to parameter analyses, the Lab also offers consultation to customers about analytical methods in general, including the proper use and care of the equipment. Finally, new analytical procedures are continually being explored and studied in order to utilize the existing equipment to its fullest potentials.

The following categories of analyses are available :

- *Chemical analysis, e.g. pH, lead, phenol, sulfate.*
- *Physical analysis, e.g. conductivity, color, salinity, specific gravity.*
- *Microbiological analysis, bacterial cell count, spore count.*
- *Heavy metals and toxic substances, e.g. arsenic, cyanide, iron, mercury.*
- *Other, e.g. ethanol, benzene, fatty acids.*
- *Special test, e.g. jar test, enzyme activity.*

Contact person:

Mrs.Suchada Chaisawart
Lab Director
E-mail: suchada@pdti.kmutt.ac.th

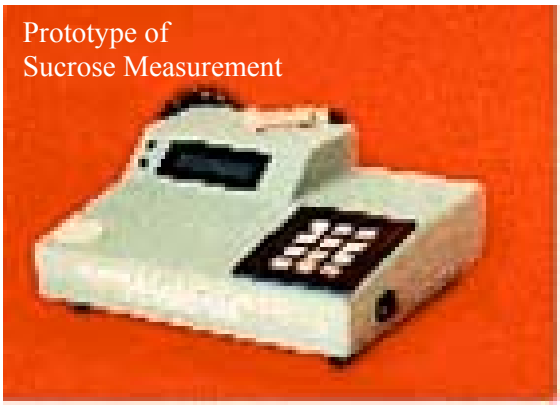
Sensors Technology Laboratory

Multidisciplinary research for foods, drinksand environmental analyses

Dr.Werasak Surareungchai
Lab Director
E-mail: werasak.suri@.kmuttl.ac.th

At KMUTT, activities in eletrochemistry and sensors research and development have arisen to meet the indigenous demands of food industry, environmental analyses, and of medical uses. Research has been made possible through the establishment of a multidisciplinary team with a diversified background, including electrochemistry, biotechnology, chemistry, materials, electrical engineering and instrumentation.

Research is carried out in three areas that want to develop the exising approaches for better performance of sensors and analytical methods, and to explore possible new applications.



1. Biosensors

- ❖ Development of biosensors and Instrumentation for the simultaneous determination of sucrose and glucose.
- ❖ Microbial BOD biosensor
- ❖ Metal-dispersed conducting polymer-Coated electrode used for oxidase-Based biosensors.
- ❖ Synthesis and electrochemical characterization of novel-redox active Biocompatible Polymer membranes.
- ❖ Screen-printed glucose oxidase eletrodes.
- ❖ Phenol enzyme biosensors.

2. Modified electrodes for electroanalysis

- ❖ Development of generator-detector voltammetric sensors for organnohalides.
- ❖ Inorganic film-modified electrode for tetracyclines determination.
- ❖ Nafion – coated probe in viscous / high resistive media.
- ❖ Metal – dispersed conducting polymer coated electrode for phenol oxidation.

3. Electroanalytical approaches

- ❖ Pulse electrochemical detection.
- ❖ Artificial neuron networks.
- ❖ Stripping analysis.

Solar Cell Systems and Energy Storage Research and Development Laboratory

Solar power as a cheap and clean alternative energy

Mr.Tawatchai Suwankum
Lab Director
E-mail: Tawatchai @PDTI..kmutt.ac.th

The Solar Cell Lab was established wish the flowing objectives to research and develop applications in the use of solar energy that are relevant to Thailand and its neighboring geographic locations, to develop industrial prototypes of solar cell systems, and to conduct research and development in energy storage systems.

The Solar Cell Lab was first established within KMUTT in 1983. Since then, the Lab has expanded to become one of the forefront research centers in Thailand involved in the research and development of solar energy applications and storage systems. Moreover, the Solar Cell Lab is now the only government service in Thailand that can certify any solar cells and photovoltaic (PV) batteries and equipment according to Australian Solar Cell Standard AS 2915-1987.

Current research includes:

- Development and commercialization of modules and prototypes of BOS (Balance of System) products. Presently, there are 3 prototypes:
  a) DC Watt-Hour Meter
  This is a second-generation prototype for measuring DC electric power with 2 input voltage ranges of 0-50 V and 0-100 V, 2 input current ranges of 0-5 A and 0-10 A, and 5-digit mechanical display.
  b) Solar Cell Pyranometer and Integrator. This is a commercial module for measuring the intensity and energy of sunlight with measuring and display ranges of 0-1500 W/sq. meter and 0-1000 kWh/sq. meter and resolutions of 1 W/sq. meter and 0.01 kWh/sq. meter respectively.
  c) Maximum Power Point Controller (MPPC). This prototype is under development in conjunction with the National Electronics and Computer Technology Center (NECTEC).
- Development of a Solar to AC (STAC) converter. This converter is researched and developed by Premier Global Co. as a transformerless DC to AC converter to connect PV arrays to main lines and tested by the Solar Cell Lab in late 1996 and early 1997 in conjunction with the National Energy Policy Office (NEPO).
- Development of generator-battery prototypes from clean energy. This project involves the design, installation, and data collection of 3 types of hybrid generator systems. They are:
  a) PV-diesel generator-battery hybrid system
  b) PV-AC generator-battery hybrid system
  c) PV-hydro-wind generator-battery system

In energy storage, the Lab is conducting conducts a feasibility study on the use of hydrogen energy and fuel cells as alternatives sources of energy in Thailand. Research focuses on the efficient production, storage, and transportation of hydrogen gas.

In addition to R&D work, the Solar Cell Lab is also heavily involved in many charity causes such as providing the use of solar energy in many rural, mountainous areas, and national parks where electricity grid lines are inaccessible. For example, the Lab is currently working on a hybrid power system that harnesses PV, hydro, and wind powers to generate electricity at wild life research stations and national parks. The Lab has also developed several types of PV water pumps that can be used for irrigation and deep-well pumping in rural villages as well as battery charging facility used for lighting in remote areas of the country.

Waste Utilization and Management Laboratory

Turning Industrial Wastes into Energy

Dr.Pawinee Chaiprasert
Lab Director
E-mail: pawinee.cha@.kmutt.ac.th

Thailand has seen a dramatic increase in industrial wastes in recent years due to the rapid industrialization in the local economy. As regulations become more strict, there is now a need to treat and utilize these wastes in the most efficient manner. For example, wastewater could be utilized for the cultivation of algae, or agro-industrial wastes could be treated biologically to produce fertilizers or biogas.

Waste Utilization and Management (WUM) at KMUTT was established to

Dr.Pawinee Chaiprasert
Lab Director
E-mail: pawinee.cha@.kmutt.ac.th

Several projects on management and utilization of wastes are emphasized and they have been used to provide technology know-how and economic data for potential users.

The WUM Lab has conducted researched into anaerobic digestion process to treat and utilize wastes from agro-industries such as the paper industry, the tapioca flour industry, the shrimp farming industry, the fruit and vegetable processing industry, etc. The WUM group has developed several high-rate anaerobic digestion systems for treating agro-industrial wastes. The innovative processes utilize novel means to retain a large amount of microbial biomass in a reactor, resulting in highly efficient conversion of organic wastes into biogas. This biogas consists primarily of methane and some CO_2, which could provide a cheap source of energy used in factories. The high-rate anaerobic digestion systems, especially the anaerobic fixed bed systems, offer many advantages over the conventional ones:

1) The systems are virtually odorless.
2) The biogas produced provides a cheap source of energy for the factory.
3) The systems are effective for both high and low BOD wastewater.
4) The systems take up much smaller space than the conventional ones with high reduction rate and low hydraulic retention time. This factor is an important consideration for factories which are located in areas where land cost is high or prohibitive.

The anaerobic fixed bed systems have been successfully installed for waste management of several agro-industrial plants in Thailand.

The WUM lab has the following focuses:

- To research and develop processes to treat and utilize industrial wastes with the initial emphasis on the production of biogas. The WUM group is also active in carrying out research programs to improve the technology, including fundamental research on the microbiology and biochemistry of anaerobic digestion as well as kinetic model, overall treatment efficiency improvement, and increasing energy recovery efficiency in industrial wastewater treatment.
- To provide technology know-how and economic data for potential users
- To design and implement a novel high rate anaerobic system in full scale
- To provide consulting service and organize workshops and seminars new paragraph Other current projects are:
  - The Acceleration Biofilm Development during Start-up Period of Anaerobic Fixed-film Reactor
  - Microorganism in Degradation of Cellulose and Hemicellulose in Anaerobic Digester of Pineapple Peel
  - Effect of Organic Acids on Methane Production in Anaerobic Digestion of Pineapple Peel

- Performance of Anaerobic Hybrid Reactor combining Upflow Sludge bed and Fixed Bed in Treating and Producing Methane from Tapioca Starch Wastewater
- Biofilm Formation in Anaerobic Hybrid Reactor
- Microbial Distribution in Anaerobic Hybrid Reactor Using 16S-rRNA FISH
- Microbial Interaction of Co-/Tri-Culture in Methanogenesis
- Mixing Characteristic of Anaerobic Hybrid Reactor
- Kinetic Model of Anaerobic Digestion and Methane Production
- The Biological Treatment of Sulfate Rich Wastewater
- Effect of Sulfate Rich Wastewater from Modified Starch on the performance of Anaerobic Digestion
- The Biological Treatment of Chlorinated Organic Compounds in Wastewater from Printing Industry
- The Acceleration of Biological Nitrogen Removal from Wastewater of Shrimp Farming
- Development, Design, Testing and Commercialization of Biolining (A New Biofilter-Design Suitable for Shrimp Culture.)

In addition to developing and engineering waste treatment systems, the WUM group is also active in providing and carrying out program on waste audit and cleaner production for agro-industrial factories.

Industrial Scale of Biogas Plant