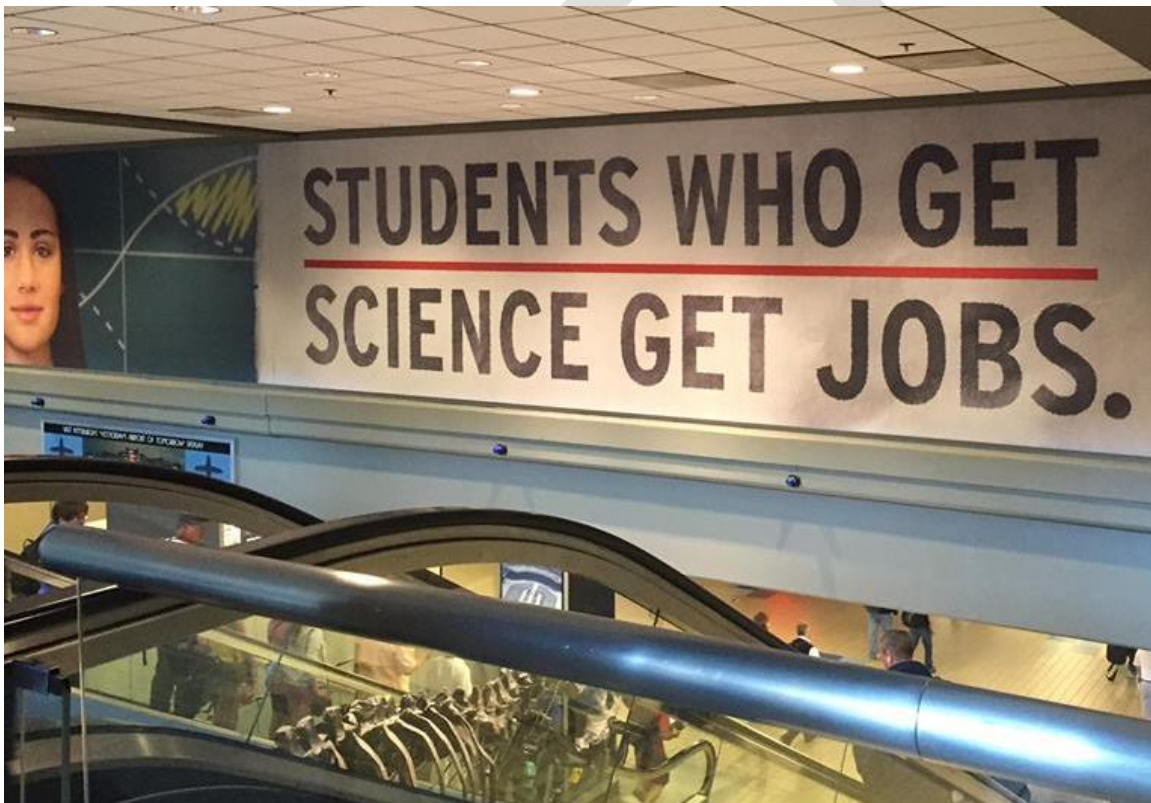




Fiscal Year 2014/2015 Annual Report

Florida Industrial and Phosphate Research Institute



The FIPR Institute and Florida Polytechnic University Get STEM (photograph taken by Indira Sukhraj at the International Science and Engineering Fair in Pittsburgh)

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Phosphate Research and Activities Board Members

Randy Avent, Florida Polytechnic University, Chairman

Terrence Baker, PCS Phosphates

Jeffrey Narrow, The Mosaic Company, Vice-Chairman

Mark Rachal, Audubon Florida

Vishwas Sathe, Florida Department of Environmental Protection

Florida Industrial and Phosphate Research Institute

Directorial Staff

Brian K. Birky, Ph.D., Executive Director, Research Director, Public and Environmental Health

Steven G. Richardson, Ph.D., Research Director, Reclamation

Patrick Zhang, Ph.D., Research Director, Mining and Beneficiation

Vacant, Research Director, Chemical Processing

Gary Albarelli, MLS, Director of Information Programs

Karen J. Stewart, MLS, Library Director

Executive Director's Message – Dr. Brian Birky

The phosphate industry plays an important role in ensuring a plentiful, low-cost food supply in the United States and helps ensure that there is sufficient food to feed a burgeoning world population. The industry also plays an important role in the economies of central and northern Florida. However, the industry's mining and chemical processing operations and the large scale of the phosphate industrial impacts raise public concerns about the environment and public health. Some of these concerns are perceived but lack scientific grounding, while some have a basis in fact.

The people in the phosphate regions worry that the industry may adversely impact the public water supply, spill acidic water or clay into the environment, and may not leave land in a useable form after mining.

The Florida Institute of Phosphate Research (FIPR) was established by the Florida Legislature in 1978 to study these issues, to help the public understand the extent and scope of any problems, and to find solutions. In 2010, the Institute's mission was expanded in legislation to include industries other than the phosphate industry and to encourage commercialization of its research products and intellectual property. On April 20, 2012, legislation was signed that immediately created Florida Polytechnic University as a new institution in the State University System of Florida. The Institute was re-established within this new university. Following the polytechnic model, the university will emphasize the application of science, technology, engineering, and mathematics.

The Institute's role is to conduct scientific investigations that will give lawmakers, regulators, members of the industry, environmentalists, and the general public the information they need to make decisions relating to issues of industrial influence or origin. Through science, we at the Institute endeavor to present the facts to the people of Florida. We strive to develop the research that will provide better solutions for phosphate industrial issues. The Institute's research principally addresses solutions for process water, clay settling areas, phosphogypsum management, reclamation science, energy and water conservation, and resource recovery.

In the Institute's 37 years of operation, it has made great strides in addressing the most vexing problems both within the phosphate industry and in the environment and communities it occupies.

Process Water - Process water is used in the chemical plant that converts mined phosphate rock into the phosphoric acid that is used to make fertilizer. There are billions of gallons of this acidic water generated in phosphate processing. Process water is

stored on and adjacent to phosphogypsum stacks that rise more than 200 feet into the air and can cover 400 or more acres of land. Our research is looking at ways to reduce the quantity and improve the quality of the water. We also study ways to clean the water so it can be safely released into the environment.

Clay Settling Areas - Phosphate rock in Florida is found in association with clay. The clay must be removed before the rock can be processed and converted into products. The clay is separated as slurry and is stored in ponds where the solid clay particles settle out over many years. The Institute's research is helping to understand how the clay settling areas impact the surface and groundwater flow in the watershed around them and how they can be reclaimed and put to environmentally sound and economically viable use.

Phosphogypsum Management – The phosphate chemical processing plants produce about 5 tons of calcium sulfate (gypsum) for every ton of phosphoric acid. This gypsum is known as “phosphogypsum” due to its origin and the small amount of phosphate it contains. Phosphogypsum contains most of the radium that was contained in the beneficiated rock used to produce it. The Institute has conducted many studies on safe and beneficial uses of phosphogypsum and has gathered international studies as well as evidence of its use as an item of commerce.

Reclamation Science – Reclamation may be defined as the process of returning mined land to a useful condition. The process includes reshaping the land and establishing vegetation. For natural systems, native plants must be established and exotic plants or weeds must be controlled. The public has expressed concerns about the value and potential/possible uses (both economic and ecological) of mined lands, the quantity and quality of surface and ground waters, and the restoration of natural ecological and hydrologic systems. The mining industry is concerned about obtaining mining permits (which require a reclamation plan) and achieving the reclamation and environmental requirements in a cost-effective manner. More recently, the possible ecological, hydrologic and economic impacts of lakes and reservoirs on reclaimed lands have come under increased scrutiny. The Institute continues to improve reclamation technologies, and to measure the success of reclamation efforts.

Energy and Water Conservation – Energy use is frequently discussed in research proposals to the Institute; mainly because energy cost may determine if a new technology can be economically applied. Water consumption and conservation is often of wider interest. The phosphate industry pumps and uses large volumes of fresh water as a necessary part of its operation, both on the mining and beneficiation sites and the chemical processing sites. Groundwater withdrawal led to serious effects in the past and is still a matter of contention. The industry has made tremendous strides in water

recycling, but improvements can be made to reduce the amount of water needed. The Institute has studied ways to reduce or replace groundwater consumption for the industry. Concern for water quality goes hand-in-hand with water conservation. The Institute has funded extensive research of the use of mined lands in water treatment. This research has been successfully applied on a large scale by the industry.

Resource Recovery – Mining has environmental and economic consequences. In order to optimize both, we should recover as much of the useful material as practical. In addition to phosphate rock, which is essential to our food security, uranium and rare earth elements are also present in the mined matrix and may be economically extracted to enhance our energy and national security. In this report, you will see that we are heavily involved in rare earth assessment and extraction research using our own funding and as part of an elite national team funded by the US Department of Energy.

The Institute has conducted research to find new technologies to: separate phosphate rock from clay and sand, rapidly settle clays and recover water, determine what rock should be left in the ground and what should be mined, remove dolomite from rock, control nuisance and exotic plants, describe the hydrology of clay settling areas, use phosphogypsum in safe and beneficial ways, recover uranium and rare earth elements, assess sulfuric acid mist exposure in the workplace, describe natural radioactivity and risk in the pre- and post-mining environment, and evaluate hazardous air pollutants in communities near processing plants.

The Institute's mission includes sharing the information it generates and collects. Toward this end the Institute routinely interacts with all stakeholders, hosts technical conferences, workshops and meetings, operates a library that is open to the public, and conducts a Kindergarten-Grade 12 education program. As our information program expands we are always looking for new ways to share our wealth of information. This report is part of that effort and is available through our web page (www.fipr.state.fl.us).

Financial Report

FIPR Institute's research and operation are funded through the Phosphate Research Trust Fund. This trust fund receives its income from a portion of the severance tax paid to the state for each ton of beneficiated phosphate rock concentrate and pebble (not dry) as measured coming off the belt at the washer of each beneficiation plant.

Since the Institute's inception in 1978, the severance tax rates, distribution, and associated fees have varied greatly, as has the rate of mining. This has, in turn, resulted in widely variable rates of income for the Phosphate Research Trust Fund. The distribution to the Institute's trust fund has varied from 5% to 12.5% of the collected tax during our history. The distribution was 6.2% July through December 2014, and 5.6% January through June 2015. The tax rate for July through December 2014 was \$1.61 per ton of rock severed, and \$1.80 January through June 2015.

Mine permitting has been a contentious issue between the industry and other entities, and the severance tax is based on mining production. The factors affecting the total tonnage of rock severed from Florida's lands also create uncertainty for planning and management of the research and operational budgets. However, the Institute strives to provide scientifically sound information to all of its stakeholders with the resources it is given.

The FIPR Institute's Executive Director provides a summary of expenditures and the trust fund balance at public meetings of the Institute's Phosphate Research and Activities Board. A more detailed summary is included herein.

Trust Fund Balance

July 1, 2014	\$8,399,762
June 30, 2015	\$7,816,771

Operations

Income

Gross Severance Tax ¹	\$1,784,472
LESS Fees to Dept. of Revenue	(\$210,866)

<u>Net Income</u>	\$1,573,607
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PLUS Interest	\$119,996
PLUS Reimbursement ²	\$3,421

<u>Total Income</u>	\$1,697,024
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Expenses

Research	(\$711,608)
Internal Operations ³	(\$1,755,677)
Reimbursement from Auxiliary Fund	\$187,270

Total Expenses (\$2,280,015)

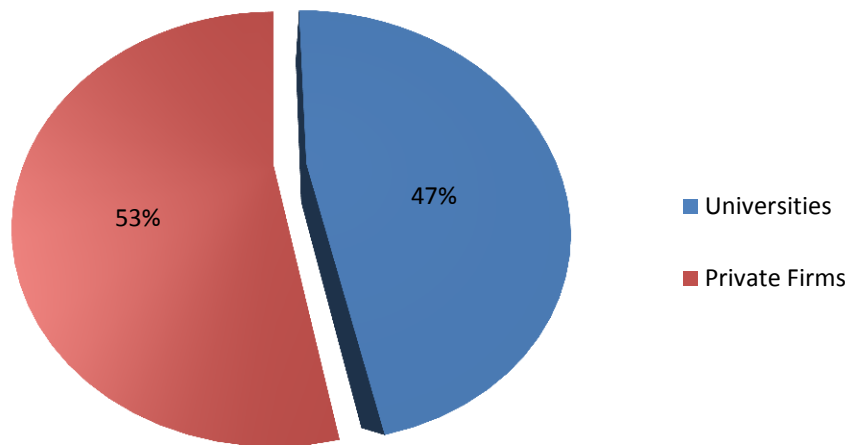
Change in Trust Fund (\$582,991)

¹Per Section 211.3103, F.S.

²Reimbursement from Division of Risk Management

³"Internal Operations" includes staff salaries and benefits, and expenses for the Education Program, Library, and Laboratories. The Institute's Research Directors and technicians (52% of the staff) spend most of their time directing or conducting research. Of the remaining staff, 24% deliver information and education services to the public and schools, and another 24% provide office and IT support within the Institute. Since "Internal Operations" also includes research done by the FIPR Institute staff, the portion of the annual income expended on research is substantial. Of the amount that is approved by our Board for specific research projects ("Research" in the summary table), the largest shares typically go to universities and private firms. Their research is conducted under the direction of the Institute.

FIPR Institute - Funded Research July 2014 - June 2015



FIPR Institute research projects approved July 1, 2014 to June 30, 2015 by percentage of total funds awarded to universities versus private firms.

Auxiliary Funds (Not from the Severance Tax)

According to Florida Statutes 1004.346 enacted in 2012, the FIPR Institute may also secure funding from grants and other available sources, enter into contracts, and provide consulting services. Revenue from these sources is deposited into an auxiliary account.

Auxiliary Account Balance

July 1, 2014	\$650,290
June 30, 2015	\$583,657
<i>Change in Auxiliary Account</i>	<i>(\$66,633)</i>

Awards and Grants (Not from the Severance Tax)

The FIPR Institute is member of the Critical Materials Institute (CMI) headed by the Ames Laboratory and funded by the U.S. Department of Energy. Since federal funding is involved, the accounting is separate.

CMI Account

Revenue	\$221,454
Expenses	<i>(\$221,454)</i>
<i>Change in CMI Account</i>	<i>\$0</i>

Community and Business Engagement

The FIPR Institute interacts with local community and business organizations in a variety of ways, such as providing our facilities for public use, participating in networking and fundraising activities, and supporting regional conferences and symposia.

The Early Learning Coalition, the Polk County School Board, Business Networking International (BNI), and the Bartow Chamber of Commerce use the FIPR Institute Conference facilities for their regular weekly and monthly meetings.

Two of the Institute's employees, Shannon Medley and Marie Wilmot, are active in the community and serve on various committees and boards.

- Shannon Medley
 - Graduate of both Bartow Chamber of Commerce Leadership and Leadership Polk
 - Serves on the Bartow Chamber Board of Directors Executive Committee as Vice President of Public Affairs
 - Chairs the two-year Leadership Bartow Program: Year 1 of 2 complete
 - Chairs Leadership Bartow Leadership Alumni Committee
 - Chairs the Bartow/Mulberry/Ft. Meade Day for Polk Vision's Leadership Polk Program
 - Serves on the Board of Directors for the Bartow Community Healthcare Foundation
- Marie Wilmot
 - Graduate of Bartow Chamber of Commerce Leadership
 - Selected (in May) as a member of Polk Vision's Leadership Polk Program - Class IX
 - Instructor at the Lake Wales YMCA and volunteers as an instructor at other community outreach facilities and events
 - Winter Haven YMCA
 - Lakeland Coleman Bush Community Center
 - Bartow Carver Recreational Center
 - Polk County School Board Employee/Retiree Health Fair
 - Bartow's Juneteenth event
 - Bartow's Relay for Life
 - Winter Haven's Fitness by the Fountain
 - Chairman for Bartow's newest fitness program - Fortress Fitness.

Awards and Achievements

There were no specific awards bestowed upon the Institute's staff during the fiscal year. However, they continue to serve on prestigious panels and committees, and their advice and counsel is in constant demand internationally.

Dr. Brian Birky is Convener of the NORM Task Force (Expert Panel) of the International Fertilizer Industry Association (IFA) Technical Committee. He and Dr. Patrick Zhang are also Technical Consultants (United States) to the International Atomic Energy Agency (IAEA).

Dr. Patrick Zhang is a member of the Editorial Board for Mineral Processing and Extractive Metallurgy Review journal. He is also Honorary Chair for the Center for Comprehensive Utilization and Sustainable Development of Phosphate Resources, China University of Geosciences. Patrick was honored to serve as Chair of Beneficiation of Phosphates VII held this year in Melbourne, Australia.

Dr. Steve Richardson is an Advisory Committee Member, Polk County Bone Valley Special Area Study. He also serves on the Lake Wales Ridge Environmental Advisory Committee.

Ms. Indira Sukhraj is an International Science and Engineering Fair (ISEF) Judge, and reviews grant proposals for National Science Teachers Association (NSTA).

Information Program

The Information Program primarily consists of the Institute's Library, widely considered the world's most extensive collection of phosphate-related reference materials, the K-12 Education Program, which brings the science of Florida's phosphate mining and processing into the classroom, and communications, which provides information on phosphate-related issues to the public. The Institute uses social media to share information about its activities and promotes the websites www.fipr.state.fl.us and www.floridapolytechnic.org.

FIPR Institute has cooperated with Florida Polytechnic to incorporate the Institute's website as an integral part of the University website. The updated FIPR Institute site has design features and elements consistent with Florida Polytechnic's site. In addition, the Institute site now resides on a common host with the University site.





To demonstrate the Institute's firm commitment to the growth and development of the University's academic and research programs, Information Program Director, Gary Albarelli, has participated with Florida Polytechnic faculty and industry partner, Mosaic, in the planning of a proposed Sustainability Lab and associated curriculum at the university. In addition, Gary Albarelli served as facilitator for the Sustainability breakout session at the second annual Florida Polytechnic Industry Partner Summit, with participation of FIPRI Executive Director, Brian Birky and FIPRI Mining and Beneficiation Research Director, Patrick Zhang. Gary Albarelli also delivered a presentation to Florida Polytechnic's Introduction to Engineering class on FIPRI, its research and information programs and possibilities for student collaboration.

The Information Program was also represented at international technical conferences during the past year through the following presentations delivered by Gary Albarelli.

- International Fertiliser Society, July 2-3, 2014, London: "Life-cycle Management of Phosphogypsum Stacks," co-authored by Brian Birky.
- Beneficiation of Phosphates VII, March 29-April 3, 2015, Melbourne, Australia: "Recovery of Sulphur from Phosphogypsum: A Historical Review and Prospects for the Future."
- Beneficiation of Phosphates VII, March 29-April 3, 2015, Melbourne, Australia: "Overcoming the regulatory hurdles to recovering rare earths from phosphate," co-authored by Patrick Zhang and Brian Birky.

The FIPR Institute Library provides books, periodicals, maps, and many other reference materials for use by the public. Everyone is welcome to use the Library, both in person and through online services, and residents with a valid Florida driver's license may check out many of the books in our collection and other specific items. The Library also participates in an interlibrary loan program to enhance accessibility to information for all members and their patrons. As a part of the State University System (SUS), the Library can also access many research articles of interest to research scientists and students. Over the past year, the FIPR Institute Library's online catalog was added to that of Florida Poly, and Florida Poly library databases became available for use by FIPR Institute researchers.

The Library continues to serve a diverse population of patrons, primarily phosphate industry professionals but also students and members of the public, answering questions and providing literature searches about phosphate mining, technology, and history; phosphogypsum technology and potential utilization of this by-product; mine reclamation; and issues concerning the environment and public health as related to the phosphate industry.

In a further effort to incorporate the Institute into the operations of Florida Polytechnic, Library Director Karen Stewart spent one day a week at the Florida Poly Library during the final semester of the last academic year, assisting Poly Library Director Dr. Kathryn Miller and Assistant Librarian Kate Bernard with various projects as requested. She will return to the Poly campus on the same weekly basis in the Fall Semester 2015.

The Library continues to support the Institute's in-house publication and technology transfer efforts. The final research report, *Peninsular Florida Stream Systems: Guidance for Their Classification and Restoration*, by Amec Environment and Infrastructure, Inc., the University of Florida, and the University of South Florida was published through the FIPR Library. It is available in PDF format from the Library's website at <http://www.fipr.state.fl.us/wp-content/uploads/2015/07/03-154-253Final.pdf>.

The K-12 Education Program continues to expand its focus to not only train teachers, but also deliver resources and content directly to classrooms in the state. In the past year, the Institute's educational resources have been brought to hundreds of classrooms, reaching thousands of Florida students directly. In addition, the variety of curriculum offered continues to grow as lesson plans, activities, and teaching units are added as a result of contributions by the Institute's staff and community teachers.

The FIPR Institute's K-12 Education Program activities for the fiscal year are summarized below.

- The FIPR Institute Education Program is constantly visiting public and private schools throughout Florida and emphasizes STEM education.

- The Institute continues to expand its offerings of STEM curriculum.
- Gary Albarelli, the Institute's Information Program Director, is on the Board of Florida Ag in the Classroom.
- Bartow Elementary Academy lists the FIPR Institute as a Corporate Partner for the school's STEM Lab and Garden.
- The Institute is involved in a variety of community education efforts. For example, Boktoberfest at Bok Tower Gardens, Central Florida Eco Tours, etc.
- Staff served as Boy Scout merit badge counselors for STEM activities.
- The Institute's Education Coordinator, Ms. Indira Sukhraj, participates in a variety of community organizations:
 - Mulberry Phosphate Museum's Advisory Board
 - Polk Regional Science Fair's SRC (Scientific Review Committee)
 - Involved with LE/AD (Lakes Education Action Drive) to educate the public about phosphate in the environment
 - Aquatics expert for Tampa Bay Regional Envirothon

Technical Exchange

In July 2014, FIPR held a workshop on rare earths and uranium recovery from phosphate processing. At this workshop, scientists from Oak Ridge National Laboratory and FIPR researchers presented their findings under the Critical Materials Institute (CMI) project funded by the U.S. Department of Energy, sought comments and suggestions from industry managers and experts, and brainstormed with the participants on project directions.

The FIPR-organized 7th International Conference on Phosphate Beneficiation took place in Melbourne, Australia, March 29 to April 3, 2015.

Brian Birky and Patrick Zhang participated in International Atomic Energy Agency (IAEA) consultants meeting on "Preparing a technical report on comprehensive extraction of uranium and associated elements from phosphates", IAEA Headquarters, Vienna, June 8- 12, 2015.

Presentations and Publications

S. Al-Thyabat and P. Zhang. "In-line extraction of REE from dihydrate (DH) and hemihydrate (HDH) wet processes". *Hydrometallurgy*, 153:30-37 (2015).

P. Zhang and C. Griffin. "Process Technology, Test Results, Plant Integration for the Removal of Mg from High Dolomite Phosphate Rock". Presented at Phosphates 2015, an international conference on phosphate, Tampa, Florida, March 25-27, 2015.

P. Zhang, et al. "Evaluation of Phosphate Depressants in the Phosphate/Dolomite System". Presented at the International Mineral Processing Congress 2014, Santiago, Chile, October 20-24.

P. Zhang, 2014. "Comprehensive Recovery and Sustainable Development of Phosphate Resources". *Procedia Engineering* 83 (2014): 37 – 51.

S. Richardson. FIPR Institute workshop: Establishment of Grass Cover on Phosphogypsum Stacks. July 30, 2014.

Chih-Hsiang Chien, Lin Shou, Alex Theodore, Chang-Yu Wu, Yu-Mei Hsu, and Brian Birky. "Development and Validation of a New Personal Sampler for Monitoring Inorganic Acid Mist and Gases." Submitted to American Industrial Hygiene Conference & Exposition (AIHce). May 30 –June 4, 2015.

Birky, B. and Albarelli, G. "The Emergence of Phosphogypsum in Global Commerce." Global SynGyp Symposium, Chicago. April 20-21, 2015.

Chih-Hsiang Chien, Lin Shou, Alex Theodore, Chang-Yu Wu, Yu-Mei Hsu, and Brian Birky. "Evaluation of aerosol penetration through a respirable personal parallel impactor." Submitted poster to PPI 2015 Poster Symposium. March 10, 2015.

Chih-Hsiang Chien, Lin Shou, Alex Theodore, Chang-Yu Wu, Yu-Mei Hsu, and Brian Birky. "A Novel Personal Sampler Design for Measuring Inorganic Acid Mist and Gases." Abstract submitted to the Association of Environmental Engineering and Science Professors (AEESP) conference. February 27, 2015.

Nils Haneklaus¹, Rolando Reyes², Wendy G. Lim², Estrellita U. Tabora², Botvinnik L. Palattao², Christina Petrache², Edmundo P. Vargas², Kazuhiko Kunitomi³, Hirofumi Ohashi³, Nariaki Sakaba³, Hiroyuki Sato³, Minoru Goto³, Xing Yan³, Tetsuo Nishihara³, Harikrishnan Tulsidas⁴, Frederik Reitsma⁴, Sandor Tarjan⁵, Karthikkeyan Sathrugnan⁵, Radojko Jacimovic⁶, Nahhar Al Khaledi⁷, Ewald Schnug⁸, Brian K. Birky, Per F. Peterson¹. "Energy neutral phosphate fertilizer production using high temperature reactors - a Philippine case study." Submitted to Philippine Journal of Science. October 24, 2014.

1 University of California, Department of Nuclear Engineering, 4118 Etcheverry Hall, Berkeley, CA 94720-1730, USA

2 Department of Science and Technology - Philippine Nuclear Research Institute, Nuclear Materials Research, Commonwealth Avenue, Diliman, Quezon City 1101, Philippines

3 Japan Atomic Energy Agency, Nuclear Hydrogen and Heat Application Research Center, 4002 Narita-cho, Oarai-machi, Higashi-ibaraki-gun, Ibaraki 311-1393, Japan

4 International Atomic Energy Agency, Division of Nuclear Power, VIC, PO Box 100, 1400 Vienna, Austria

5 International Atomic Energy Agency, Terrestrial Environment Laboratory, 2444 Seibersdorf, Austria

6 Jožef Stefan Institute, Jamova cesta 39, 1000 Ljubljana, Slovenia

7 Radiation Protection Department, Mubarak Al Kabir Street, PO Box 16087, 35851 Qadeseyah, Kuwait

8 Braunschweig University of Technology, Department of Life Sciences, Pockelstraße 14, 38106 Braunschweig, Germany

Chih-Hsiang Chien, Lin Shou, Alex Theodore, Chang-Yu Wu, Yu-Mei Hsu, and Brian Birky. "Development and Validation of a New Personal Sampler for Monitoring Inorganic Acid Mist and Gases." Submitted abstract for 2015 AIHA meeting. September 22, 2014.

Chih-Hsiang Chien, Lin Shou, Alex Theodore, Chang-Yu Wu, Yu-Mei Hsu, and Brian Birky. "A New Personal Sampler for Measuring Inorganic Acid Mist and Gases: the Validation Test." 2014 International Aerosol Conference, Busan, Korea. Aug. 28 – Sep. 2, 2014.

Chih-Hsiang Chien, Lin Shou, Alex Theodore, Chang-Yu Wu, Yu-Mei Hsu, and Brian Birky. "Performance Characterization of a New Personal Sampler for Measuring Inorganic Acid Mist and Gases." 2014 International Aerosol Conference, Busan, Korea. Aug. 28 – Sep. 2, 2014.

Birky, B. and Albarelli, G. "Life Cycle Management of Phosphogypsum Stacks." International Fertiliser Society, London. July 2-3, 2014.

In-house Publications

FIPR Publication No. 02-184-250 “New Mobile Pre-Processing Equipment for Florida Phosphate Mining.” Dr. Hagen Muller, HAVEREngineering GmbH. June 2014.

FIPR Publication No. 03-150-251 “Hydrology of a Clay Settling Area.” Mark Ross, Mark Stewart, Ken Trout and Mark Rains, Center for Modeling Hydrologic and Aquatic Systems Department of Civil and Environmental Engineering and Department of Geology University of South Florida. June 2014.

FIPR Publication No. 04-076-252 “Industrialized Remote Real-Time Analyses of Phosphate.” Michael Gaft, Laser Distance Spectrometry with Regis Stana, R Squared S, Inc. April 2015.

FIPR Publication No. 03-154-253 “Peninsular Florida Stream Systems: Guidance for Their Classification and Restoration.” John H. Kiefer and Kristen B. Nowak, AMEC Environment and Infrastructure, Inc.; Joann Mossa and William R. Wise with Kenneth M. Portier, University of Florida; Thomas L. Crisman, University of South Florida. June 2015.

Research Areas

Projects were funded from the Phosphate Research Trust Fund and managed by the FIPR Institute. Typically, some projects are conducted in-house while many are conducted by various universities and private companies. FIPR Institute Research Directors serve as Contract Managers for all projects. Projects that were completed, ongoing, or initially funded during the fiscal year are described in the following text and organized according to the Institute's research areas.

Research projects, however, often pertain to more than one of the Institute's research areas because they have components that fit under more than one heading. For example, research on phosphogypsum, a by-product of phosphate fertilizer production, may include chemical processing of the phosphate, production and treatment of the process water, use of the by-product, public health, and reclamation of a closed phosphogypsum stack.

The Institute's Strategic Plan, available on our web site, covers the period 2011 to 2016 and was presented to the Institute's Advisory Board and the public in January 2011. After revision, its adoption was recommended by the Board at the January 2011 meeting and it was adopted on February 17, 2011. It discusses goals and approaches to achieve them in each of the Institute's research and programmatic areas. Although substantial progress has been made towards achieving these goals, more work is still needed. In addition, the plan contains new goals and approaches applicable to non-phosphate work.

Progress made in this fiscal year in Mining and Beneficiation, Chemical Processing, Public & Environmental Health, and Reclamation is described in the pages that follow. The Institute's projects that are funded by the Phosphate Research Trust Fund are directed at solving real-world problems identified with the mining and processing of phosphate rock in Florida in which the public has a substantial interest. Summaries of the Institute's research are provided in categories of completed projects, ongoing projects, and projects funded this fiscal year. In each category, the projects are described by title, funded organization, and a brief description of the objectives and accomplishments.

Mining and Beneficiation

Completed Projects

Remote Real-time Industrialized Analyzer of Phosphate Rock R Squared S, Inc.

A decade-long research collaboration between Dr. Gaft of Laser Distance Spectrometry (LDS) of Israel and the FIPR Institute has resulted in the development and commercialization of the world's first on-line analyzer (Maya) for wet minerals using the laser-induced breakdown spectroscopy (LIBS) technology. Although the original objective of the on-line LIBS analyzer was to determine dolomite content, much more has been accomplished. The commercialized analyzer not only gives dolomite readings with acceptable accuracy, but also analyzes or calculates contents of other important components such as BPL, CaO, minor element ratio (MER), Fe_2O_3 , Al_2O_3 and Insol. Another nice feature of the analyzer is remote, wireless operation. According to an industry estimate, one installation of Maya at a phosphate beneficiation plant could bring an annual economic benefit of about \$3 million.

The application of ore evaluation in the exposed mine face and in the dragline bucket can increase reserves by including phosphate deposits with high Mg content from southern Florida in economically viable production. Because of selective excavation and dumping, most of the dolomite will be separated near the open pit, thus reducing ore transportation costs significantly. An additional advantage may be the lowering of energy use and flotation chemical consumption, because ore with excessive contaminants will be removed before expensive grinding and flotation processes.

The FIPR Institute and the Israeli research team have long set the goal of developing a LIBS-based analyzer for remote analysis of ores and overburden before these materials are excavated or are in transit to the beneficiation plant. The many years of research and development of the on-line analyzer have laid a sound foundation for developing a version of LIBS that can analyze materials at a great distance, i.e. a "remote LIBS". The successful commercialization of the on-line LIBS encouraged FIPR to fund research on the remote LIBS.

Under phase one of the remote LIBS program, distant evaluation in the lab and field testing of a remote LIBS prototype demonstrated its feasibility for distant (from 5-25 m), real-time chemical analysis of phosphate minerals excavated by the dragline machine. Analytical data from the remote LIBS correlated well with laboratory analyses, giving a

correlation coefficient of $R^2 = 0.915$ for P_2O_5 and 0.75 for MgO . In the current project, an industrialized unit was constructed and tested, capable of continuous functioning in operating conditions of the open phosphate mine. The unit proved to be robust, and gave reliable and useful information on phosphate matrix during the course of its discharge from dragline bucket to the slurry pit. However, it was determined that in order to take full advantage of remote analysis, the analyzer would have to be mounted on the dragline, which is a big engineering challenge and is costly to develop.



Industrial prototype remote LIBS analyzer.



Mobile Prototype Remote LIBS Analyzer in Operation.

Isolation and Characterization of RE Mineral Particles in Florida Phosphate Rock by DE Rapid Scan Radiography and HRXMT

University of Utah

Rare earth elements (REE) are critical to national security from the Department of Defense to Homeland Security; to the development of green energy as used in hybrid cars and wind turbines; and to advancement of various high-tech fields such as computing and internet technology. They are also vital to many traditional industries such as petroleum refining and glass polishing. The U.S. faces a critical shortage of these elements. The demand for these elements cannot be presently met directly from rare earths mines, and alternative sources must be found to fill this need. Florida phosphate could be one of the alternative sources. FIPR recently conducted a characterization study of REE in Florida phosphate, and found appreciable amounts of REE in currently mined ore, with one flotation concentrate analyzing above 900 ppm of total REE. In Florida, approximately 30,000 tons of rare earth elements are discarded annually in various phosphate mining and processing streams, while the current U.S. demand for REE is less than 15,000 tons per year.

The high potential to meet the entire U.S. demand by recovering REE from Florida phosphate prompted FIPR to team up with the Oak Ridge National Laboratory (ORNL) in applying for a \$120 million funding award by the U.S. Department of Energy (DOE) to establish a new Energy Innovation Hub on critical materials. FIPR and ORNL decided to join the Critical Materials Institute (CMI), led by the Ames Laboratory. CMI succeeded in securing the DOE funding in early 2013, and FIPR was awarded a five-year contract to work on the project “Recovery of REEs and Uranium from Phosphate Ore Processing”. This University of Utah study on isolation and characterization of rare earths mineral particles in Florida phosphate rock was funded because it complements the FIPR efforts under the CMI project.

Since REE-containing minerals exist in phosphate processing streams within ppm ranges, identification and quantification of these minerals are nearly impossible using traditional X-ray diffraction and microscopic methods. This project was designed to isolate and analyze rare earths-containing minerals in phosphate mining and processing streams using the most advanced mineral characterization techniques, high-resolution X-ray micro tomography (HRXMT) and dual-energy (DE) rapid scan radiography. This type of information is critical to developing methods for extracting rare earth elements from phosphate.

Results from this project show that DE radiography followed by HRXMT scanning is an effective and efficient method for resource identification in general, and is particularly well-suited for REE mineral identification. One major REE mineral identified in all samples is monazite, which may be one of the reasons why a majority of the REE in phosphate rock reports to phosphogypsum during the acidulation process, since monazite is difficult to dissolve at low temperatures. One of the remaining challenges in characterizing REE minerals in phosphate is to analyze the amount of REE as calcium substitution in phosphate crystals.

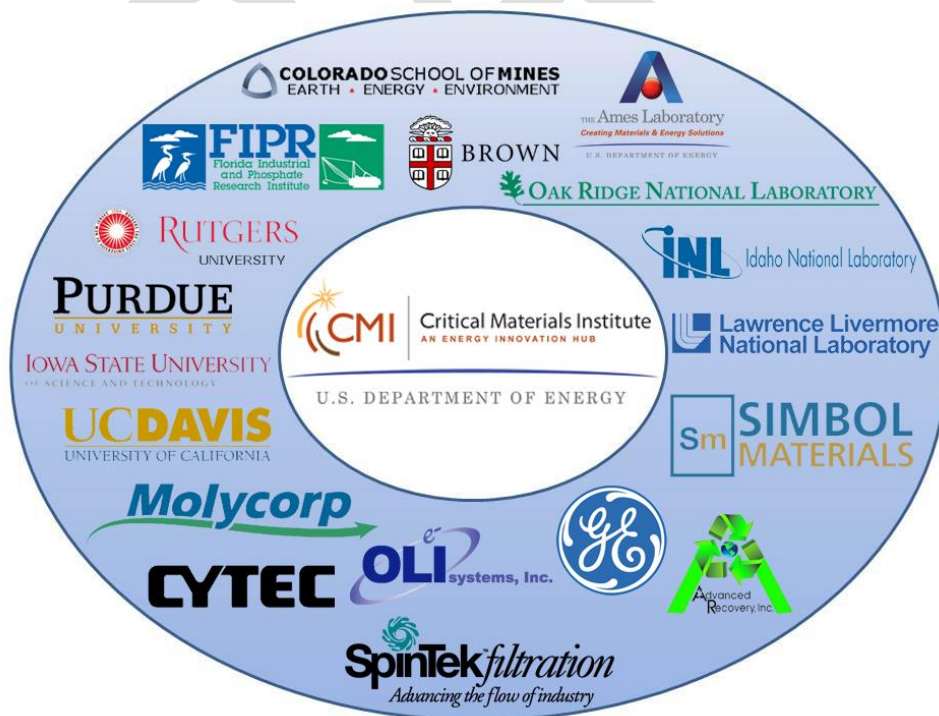
This research was designed to provide guidance for developing mineral separation and metal extraction technologies for recovering REE from Florida phosphate. Two advanced mineral characterization techniques are used in this research: High resolution X-ray micro tomography (HRXMT) and Dual energy (DE) rapid scan radiography. Three sample streams, Shaking Table Concentrate, Acid Plant Feed, and Phosphogypsum, were separated into three size classes: $>106\text{ }\mu\text{m}$, $75\text{-}106\text{ }\mu\text{m}$, and $53\text{-}75\text{ }\mu\text{m}$. DE radiographs were taken at two energy levels and the ratio calculated. The images were “thresholded” to show only potential rare earth particles and then those particles were removed to prepare HRXMT samples. The samples were digitally reconstructed and the concentration of rare earth particles found using digital processing software. The overall concentrations for the three size classes were found to be 2157 ppm in the Shaking

Table Concentrate, 104 ppm in the Acid Plant Feed, and 284 ppm in the Phosphogypsum, respectively. Based on the degree of liberation, the best particle size to find fully liberated monazite particles is 75-106 μm , although other sizes can reasonably be considered for Acid Plant Feed and Phosphogypsum. The project will determine the occurrence of REE in tailings & waste clay, identify and quantify REE minerals in phosphate rock, characterize REE forms in phosphogypsum, and investigate liberation of REE minerals in ground and unground phosphate rock.

Ongoing Projects

The CMI Project - Recovery of REEs and Uranium from Phosphate Ore Processing FIPR

In early 2013, the US Department of Energy (DOE) awarded \$120 million to the Critical Materials Institute (CMI) to establish a new Energy Innovation Hub. CMI focuses on developing and commercializing advanced technologies to secure the national supply for critical materials, particularly rare earth elements (REE). FIPR is a member of CMI undertaking the project on recovery of uranium and REE from phosphate mining and processing products as well as byproducts. All the CMI members are shown in the figure below.



CMI member universities, national laboratories, and industry partners.

This annual report coincides with CMI's second anniversary. During the past two years, FIPR has made significant progress in concentrating REE from various phosphate mining and processing products and byproducts, and extracting REE using different leaching techniques. As a result, the FIPR project has become one of CMI's most-bragged-about successes. Although the CMI budget for Year 3 was cut by 20%, FIPR received \$90,000 extra, an indication of CMI leadership's confidence in the FIPR efforts. The major FIPR achievements under the CMI project are summarized as follows:

1. Gained better understanding of rare earths occurrence in phosphate rock, phosphate flotation tailings, phosphogypsum (PG), acid sludge, and phosphoric acid, thus being able to develop suitable beneficiation and extraction schemes for each stream
2. Conducted two in-plant pilot testing campaigns to concentrate REE minerals from waste clay and amine flotation tailings, with shaking table testing achieving roughly 50% REE concentration in about 6% of the total mass of flotation tailings
3. Developed a multi-stage leaching scheme for recovering REE from PG using dilute sulfuric acid without infringing on the regulatory conditions of PG
4. Discovered a significant REE source material: sludge from phosphoric acid concentration/clarification.



Dr. Haijun Liang, Post-Doctoral Associate from Columbia University, conducts continuous, pilot scale shaking table concentration of REE minerals from flotation tailings at a Mosaic mine.



Continuous, pilot scale hydrocyclone concentration of REE minerals from waste clay at a Mosaic mine.

*Improving the Dolomite Flotation Technology for Florida Phosphate Pebbles:
Removing the Last Hurdle to Commercialization*
FIPR-Bluestar Lehigh Engineering Corporation

In collaboration with Jacobs Engineering, IMC, Mosaic and China Bluestar Lehigh Engineering Corporation (Bluestar), FIPR has developed a feasible technology for processing the high-dolomite phosphate pebbles in Florida. The process involves grinding the pebbles to liberate dolomite, dolomite flotation with phosphoric acid as a phosphate depressant, and silica flotation. In 2000, pilot testing was conducted on two pebble samples with Pebble #1 analyzing 3.5% MgO and Pebble #2 containing 2.8%, achieving more than 67% MgO removal at over 75% P_2O_5 recovery. Feasibility analysis by Jacobs Engineering demonstrated both the technical and economic feasibility of the dolomite flotation process. For a 300 tph battery limits beneficiation plant employing the FIPR beneficiation process, the construction cost was estimated to be 32 million dollars with a total operating cost of \$15.62 per ton of concentrate. These numbers were considered to be very competitive.

Encouraged by these results, Mosaic conducted further testing and had decided to build a plant for processing their high dolomite reserves at the Four Corners mine. However, the project was suspended indefinitely due to the concern about treatment cost for P-containing waste water.

This new project is designed to further improve the dolomite flotation technology thus providing the industry with more confidence in commercializing the process. The proposed research includes the following five major components: 1) water balance analysis for the dolomite flotation plant to determine whether the flotation water could be recycled 100%; 2) modification of the dolomite flotation process by using less or zero phosphoric acid; 3) evaluation of strong phosphate depressants; 4) feasibility and environmental analysis; and 5) technology transfer workshop.

The project has achieved new breakthroughs in the following three aspects:

1. Dolomite flotation without using phosphoric acid
2. A new, more selective dolomite collector that performs well in sulfuric acid only
3. A new phosphate depressant, which could improve P_2O_5 recovery by over 3%.

Extraction and Recovery of Rare Earth Elements from Phosphate Using PX-107 and Chelok® Polymers

Periodic Products, LLC

Periodic Products has developed a series of unique, insoluble, non-toxic, biodegradable polymer compounds for removing metals from water. These products have the following features: 1) high adsorption capacities, 2) easy separation of metals from the polymer, 3) amenable to solutions of different pH values, and 4) capable of removing +1, +2, +3 and +4 ions. In addition, Periodic Products has developed some proprietary aqueous based leaching agents for extracting metals from solid materials.

In 2013, Periodic Products initiated an in-house research program on REE extraction from phosphogypsum, and developed a two-step technology. In the first step, dry PG was ground and extracted with Periodic Products' proprietary extraction solution, PX-107, achieving 72-100% dissolution. In the second step, the leaching solution was treated with Chelok® Polymers to remove REE from the solution, resulting in removal of 94-100% of the dissolved REE from PG. Preliminary economic analysis showed positive return on investment in the technology. Preliminary experiments using waste clay and flotation tails also achieved encouraging results.

The FIPR Board awarded Periodic Products a grant to demonstrate the efficacy of their technologies on various intermediate products and by-products of phosphate mining and phosphoric acid production, including phosphate rock, phosphoric acid, waste clay, flotation tailings, and phosphogypsum.

Some promising results have been achieved, demonstrating efficient REE absorption using the polymer. This is significant, because the polymer is many orders of magnitude cheaper than any solvent extraction system currently utilized on commercial scale.

Projects Funded This Fiscal Year

REE Enrichment from Phosphate Tailings through Bio-Leaching Followed by Ion Flotation: An Exploratory Research Project

Columbia University/University of Florida

A recent FIPR characterization study shows that the amine flotation tails contain roughly 10% of the total REE in Florida phosphate matrix. REE minerals in this byproduct are relatively easy to concentrate by gravity separation or flotation. However, conventional technology for recovering REE from this type of material involves high temperature

leaching, solvent extraction, and numerous complicated separation steps. This research aims at developing alternative, energy saving and environmentally friendly methods using bio-leaching based technology for rare earth dissolution and a ion flotation based method for recovering REE from solution. Three different types of bacteria capable of leaching REE minerals and a total of 8-10 strains will be evaluated. In the supplementary steps, chemicals (ammonium sulfate and sulfuric acid) might be considered to enhance leaching kinetics. The objective of the multistep bio-leaching schemes is to understand how the individual bacterium contributes to overall leaching kinetics. As a key part of the bioleaching strategy, pretreatment of the tailings prior to bioleaching will be carried out using froth flotation or gravity separation techniques to concentrate REE containing materials. Leaching efficiencies will be examined under a set of different media compositions and leaching conditions. Renewable and cheaper raw material resources will be evaluated as media constituents. The leaching studies will be carried out using a column leaching method. Subsequent to bio-leaching, enrichment of the REEs from the leached liquor will be carried out using ion-flotation. A number of chelating agents including oximes (ketoximes and/or aldoximes), EDTA and bacterial extracellular enzymes will be considered.

Chemical Processing

Progress in chemical processing research was hampered by both the vacancy of the Research Director's position. Nevertheless, progress has been made in fulfillment of the Institute's mission. We have made a concerted effort to upgrade the Institute's laboratories to support research in chemical processing as well as ore characterization and beneficiation. Laboratory facilities include an Analytical Chemistry Lab (with a wet bench chemistry room and a separate analytical instrument room), and a Metallurgical Lab (with an adjacent secure outdoor compound). Instrumentation and procedures have been updated and enhanced to improve the range and quality of analyses we perform.

A partial list of analytical capabilities and instruments includes:

- Sample preparation: homogenization, cone and quartering, Bico rock crusher (Jaw crusher), grinding (Bico-Braun ball or rod mill and Bico-Braun Pulverizer/grinder), Blue-M drying ovens, Tyler Ro-Tap, sieve screening (wet & dry), riffle sample splitter
- IEC Centrifuge
- pH/ISE meter
- X-ray diffraction
- Petrographic microscope analysis
- P₂O₅ and CaO analysis (Lachat QuickChem 8500 Series 2 Flow Injection Analyzer)
- Inductively Coupled Argon Plasma (ICP-OES) analyses (Perkin Elmer Optima 8300 Spectrometer)
- Inductively Coupled Argon Plasma (ICP-MS) analyses (Perkin Elmer NexION 350X Mass Spectrometer)

Special sample preparation and/or procedure methods include:

- Heavy mineral separation
- Magnetic separation
- Electrostatic separation
- Sonic sieving
- Cyclosizing
- Insol determinations
- ICP select elements (including uranium and rare earth elements)

Chemical analyses are performed with the most recent methods described in the Association of Florida Fertilizer and Phosphate Chemists (AFPC) manual. Only minor

modifications are made to accommodate instrumentation available at FIPR Institute, but quality assurance is verified using controls and standards. Reagents are ACS reagent grade and volumetric glassware is class A, as required. Analytical results of phosphate rock samples are monitored by analyzing AFPC-certified Check 22 standards along with the project samples. Spikes are incorporated to monitor recovery of cations by the ICP.



Perkin Elmer NexION 350X Mass Spectrometer.

Ongoing Projects

Sulfur Recovery from Phosphogypsum FIPR

There has been great interest in the Institute's efforts to recover elemental sulfur from the phosphogypsum (PG) produced by the global phosphate fertilizer industry. The motivation for this recovery is varied. In the United States, the recovery would give a company control over their sulfur supply and be attractive economically when the widely

cyclical price of sulfur remains high. Sulfur recovery is more compelling in regions where native sulfur is unavailable or where phosphogypsum accumulation is not tolerated. In China, in addition to the economic benefit whereby the Chinese would not have to import sulfur from Canada, there is also the immediate regulatory requirement to consume 20% of phosphogypsum produced.

Many process routes, both chemical and biological, have been explored to use PG as a source of sulfur, but all require considerable energy inputs. The recovery of sulfur from PG is unlikely to be economically competitive against inexpensive by-product sulfur from the oil and gas industry. However, because of the considerable costs of stacking PG, recovering sulfur from PG could become worthwhile. Since radium and calcium are chemically similar, it is likely that the radium in the PG would migrate with calcium. For example, in the production of ammonium sulfate from calcium sulfate, the calcium carbonate by-product would retain the radium, leaving the ammonium sulfate produced free of radium and the subsequent radon scrutiny it creates. The radiological aspects of biological recovery processes for sulfur have not been studied, although the radionuclides would be expected to remain in the residue leaving the sulfur essentially free of radioactivity.

Traditional sulfur dioxide recovery schemes all face the same basic drawbacks. First, as phosphate fertilizer facilities have incorporated electricity cogeneration capabilities to power their operations, the importance of capturing the maximum amount of heat in the production of sulfuric acid has become a priority. Having the sulfur enter the process as sulfur dioxide eliminates the substantial heat of combustion of sulfur from the equation. In addition, the SO_2 produced from phosphogypsum conversion is only at a 6% stream, resulting in a de-rating of the sulfuric acid production capacity that requires 12%. Even the FIPR circular grate process, which achieved an 8% stream through the addition of pyrites to the grate, would still fall far short of system requirements.

Recent FIPR efforts to examine alternatives for sulfur recovery have focused on gypsum conversion to hydrogen sulfide and then to elemental sulfur through the traditional Claus process. The advantages of recovery of sulfur when compared to known technologies that recover sulfur dioxide as discussed should displace other means of sulfur recovery. Once reliably demonstrated, it is anticipated that there will be wide interest in implementation of the technology as regulatory pressures to consume phosphogypsum to avoid environmental risks associated with stacking expand globally. However, it is possible that other technologies to accomplish this may be developed in the future.



Dr. Zhen Jin (L) and Abner Gonzalez (R) use a tube furnace to break down phosphogypsum with H_2S monitoring.

FIPR compared the energy balances of the traditional sulfur dioxide route, which has proven to be uneconomical, and the proposed hydrogen sulfide routes. The study also incorporated production of cement clinker from the calcium by-products. The study clearly showed a substantial energy advantage using the hydrogen sulfide route. In addition to the stated energy advantage, there exists a strategic advantage for phosphate producers to maintain control of their own sulfur supply. Producers would be much less vulnerable to sulfur price spikes and demands of sulfur suppliers. Also, transportation costs associated with sulfur delivery would be manageable.

Preliminary laboratory studies of the preferred process route reactions have shown great promise and work continues to refine them.

Public & Environmental Health

Completed Projects

Radiation Doses and Risks from Fertilizer Production and By-Product Phosphogypsum Use

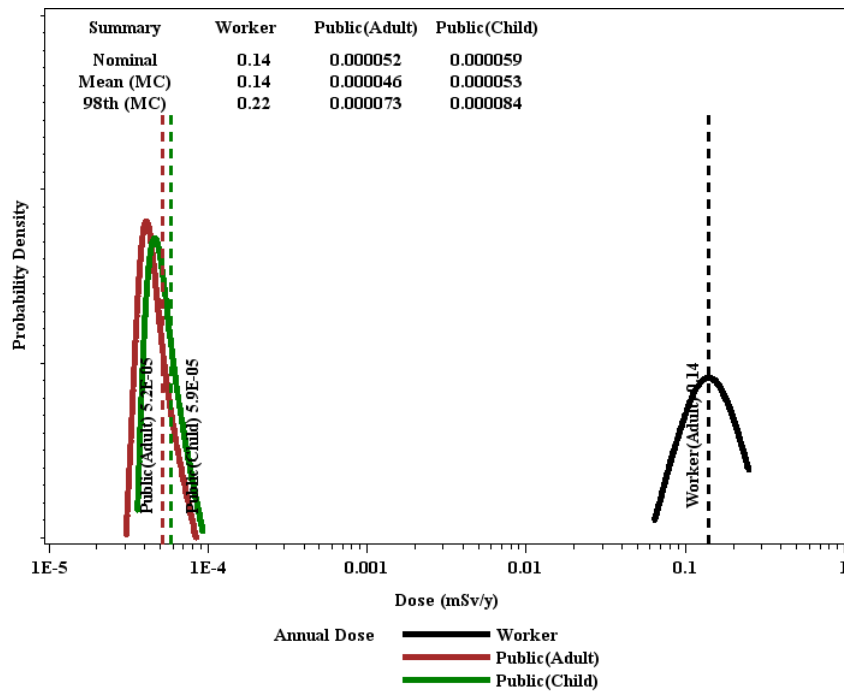
SENES

SENES was contracted to conduct a radiological risk assessment resulting from releases of the main naturally-occurring radionuclides (^{238}U , ^{235}U , ^{226}Ra , ^{232}Th , ^{228}Ra , ^{210}Pb , ^{210}Po , ^{214}Bi , ^{214}Pb , ^{40}K) to the environment using EPA-approved models (e.g., RESRAD, AERMOD) to the extent possible. This report provides the results of an evaluation of the radiation doses and consequent (lifetime) risks that are associated with phosphate fertilizer production and with potential alternative uses of PG, in agriculture, as daily landfill cover and as road base.

EPA concluded in 1992 "*that certain uses of PG may be considered acceptable so long as those uses are restricted to limit the estimated lifetime risk to any individual to no more than 3 in 10 thousand*" (57 FR 23312, 3 June 1992). The radioactivity in phosphate ore and PG varies by location. For example, Northern Florida PG has Ra-226 concentrations of 10 pCi/g (0.37 Bq/g) or less while PG from Central Florida PG has Ra-226 concentrations of about 26 pCi/g (0.962 Bq/g). The present analysis assumes Ra-226 concentrations of about 1 Bq/g, consistent with the levels seen in Central Florida.

The approach to dose and risk assessment described in the present report is to first perform a base case assessment which is then followed by an uncertainty analysis intended to provide insight as to how confident we can be about the estimated doses and risks. The approach employs base case dose assessments using "nominal" but in the authors' opinions, conservative values for locations relative to the activity, model inputs and parameter values. Doses and risks are assessed for workers, and both adult and five-year-old members of the public.

The intent of the base case was to predict dose (and risk) for the groups considered likely to be most exposed. The base case does not reflect the general exposures to the entire population as most public receptors would receive much lower doses than those estimated to these reasonably maximally exposed receptor groups.



Example of Annual Dose (mSv/y) with Uncertainty for Road Use of PG.

The following table provides a summary of annual doses (and associated risks from a lifetime of exposure) for each of the scenarios and receptors assessed in this report, all of which are show lifetime risks estimated to be well below the EPA's reference (lifetime) risk level of 3E-04.

While the doses and risks to reasonably maximally exposed receptors shown in the table are all quite small, there is uncertainty about the doses and risks due to uncertainty or variation in the inputs used in the dose models. Uncertainty analysis was done to investigate these issues and was performed using distributions of key model inputs that have been developed in this study. These distributions incorporate varying degrees of uncertainty and/or individual variability. The combination of the uncertainty arising from the lack of knowledge and variability arising from natural variation are included in this "uncertainty" analysis.

Summary of Doses (mSv) and Lifetime Risks from Base Case.

Attribute	Worker	Adult	Child
Phosphate Fertilizer Production			
Annual Dose (mSv/y)	0.034	0.016	0.02
Lifetime Risk	7.0E-06 (5 y)	1.9E-05 (30 y)	.
Agriculture			
Annual Dose (mSv/y)	0.0096	0.067	0.077
Lifetime Risk	3.2E-06 (8 y)	8.3E-05 (30 y)	.
Landfill			
Annual Dose (mSv/y)	0.29	0.009	0.011
Lifetime Risk	6.0E-05 (5 y)	1.1E-05 (30 y)	.
Road			
Annual Dose (mSv/y)	0.14	5.2E-05	5.9E-05
Lifetime Risk	2.9E-05 (5 y)	6.4E-08 (30 y)	.

Note: Value in brackets for lifetime risk is the base case duration of exposures.

The uncertainty analysis was performed with Monte-Carlo simulation to produce a (subjective) probability distribution of model predictions. The results of the uncertainty analyses were summarized to produce the mean, or expected value, of the result along with an upper percentile (the 98th percentile was used here) to reflect a value that is unlikely to be exceeded for the scenario and described uncertainties. The upper percentile values were also well below the annual dose limit and the EPA's accepted 3E-04 lifetime risk limit.

This assessment indicated that beneficial uses of PG including use as soil amendment in agriculture, as daily landfill cover and as road base can be considered for use since the annual doses and upper percentile predicted doses from a conservative assessment approach are very unlikely to exceed levels considered by EPA as safe.

Ongoing Projects

Commercial Development and Validation of a Disposable Personal Sampler for Inorganic Acid Mist Measurement

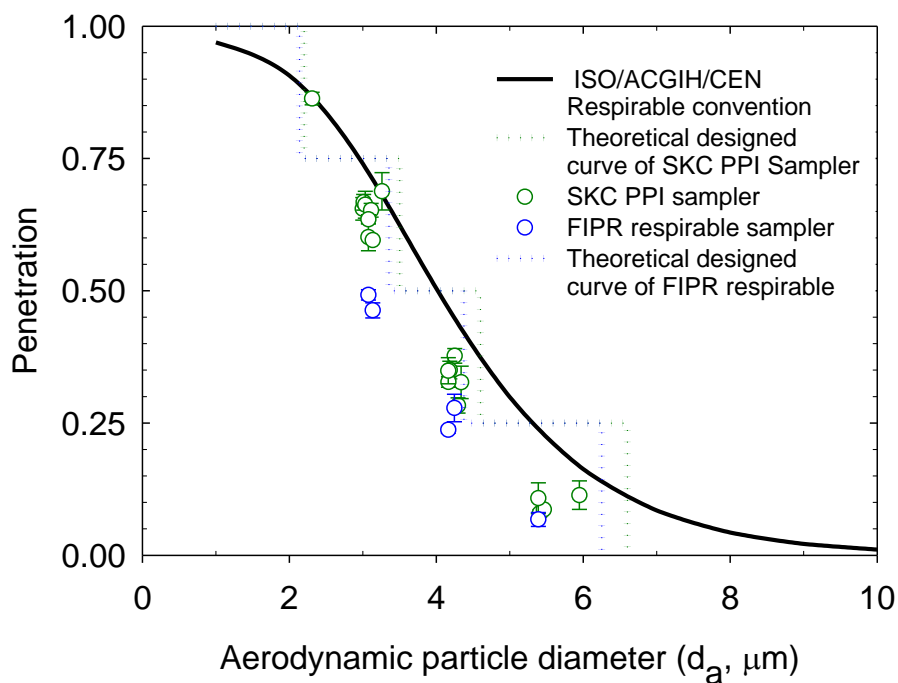
University of Florida

This is a continuation of previous research requested by the phosphate industry in response to new lower exposure limits that were proposed based on decades old measurements that are not representative of the modern facilities. A series of studies were conducted. The first study indicated that sulfuric acid mist exposures to Florida phosphate industry workers are below the new, more restrictive standards. However, the standard method used to measure sulfuric acid concentration overestimates those concentrations in sulfuric/phosphoric acid manufacturing plants and could result in reports of excessive exposure when they have not actually happened. Subsequent studies identified the physical sources of the errors and described methods to exclude them and correct the method. Finally, a porous membrane denuder (PMD) that excludes interfering aerosols from the sampling stream to give a more realistic measurement of the acid concentration in air was designed, constructed and patented.

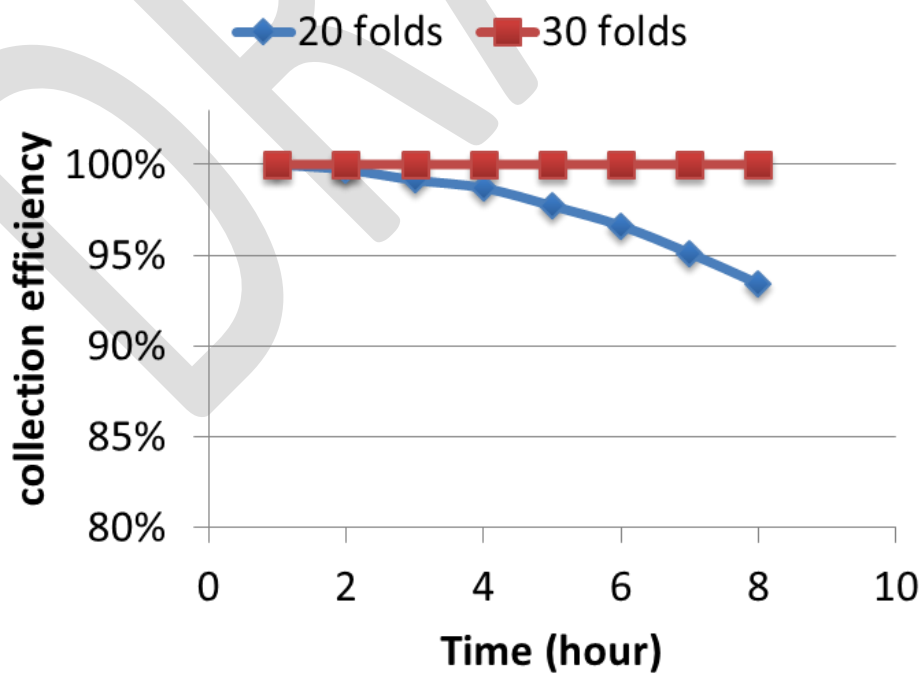
The current study is designed to transform the FIPR personal sampler prototype into a ready-to-manufacture commercial sampler. Modifications that are critically important to the commercialization of the sampler include a completely disposable and ergonomic design, and adaptation to the new thoracic fraction standards set by European Union. The commercial prototype will be validated by scientists at OSHA's Salt Lake City Testing Center. In addition, the project will explore the sampler's feasibility for ammonia adsorption to expand its capability from acidic to basic gases. The current design, PMD IV, has the capacity to absorb 10 ppm SO₂ for 8 hours and co-sample HNO₃, HCl, and SO₂ for 4 hours. SO₂ is almost entirely collected by denuders. No SO₂ interference occurs in other parts of the personal sampler. Such interference would result in overestimation of the actual exposure to sulfuric acid mist in the workplace.

- PMD IV has the capacity to absorb 10 ppm SO₂ for 8 hours, and co-sample HNO₃, HCl, and SO₂ for 4 hours.
- The personal sampler's analyte recovery of H₂SO₄ mist under both low and high RHs was higher than 99%, indicating no significant interference.
- SO₂ was almost entirely collected by denuders. No SO₂ interference in other parts of the personal sampler.
- Ambient and refrigerator storage methods impose no significant effect on the denuders.

- Testing results of oleic acid droplet follow the respirable convention.



- 30-fold accordion-shaped denuders can collect 10 ppm NH_3 well at both high and low RHs.



Reclamation

Completed Projects

Hydrology of Clay Settling Areas University of South Florida

There are more than 120,000 acres of clay settling areas (CSAs) in Florida. What effects are these areas having on the surface and ground water regimes in the basins where phosphate mining occurs? How do CSAs behave hydrologically, and how can this behavior be modeled and predicted? How should CSAs be designed and reclaimed to optimize their hydrologic functionality? It is important to understand and be able to predict internal and external hydrologic relationships. The internal CSA hydrology is related to supporting functional wetlands on a CSA, and the “external” hydrology is related to impacts on surrounding surface and ground water systems.

Previous research has shown the importance of water storage in depressions and surface desiccation cracks. In addition, the depressional storage increases with time following reclamation due to further clay consolidation and surface subsidence. Progress has been made in improving the ability to predict clay consolidation and to account for it in modeling CSA hydrology. However, uncertainties in making accurate estimates of evapotranspiration and ground water seepage still remained. This project evaluated and modeled the complete water balance of a CSA and included methodology for more accurate determination of evapotranspiration and ground water seepage. One interesting finding was that the vertical and horizontal permeability of the top meter of clay is much greater than previously thought due to cracks and old root channels.

The final report “Hydrology of a Clay Settling Area” is available on the Institute’s website as FIPR Institute Publication No. 03-150-251. An intensive data collection and modeling study was undertaken to better understand the hydrologic functioning and impact of clay settling areas (CSAs) associated with phosphate mining on surrounding water bodies and aquifers. Data were collected and a surface (HSPF) and groundwater (MODFLOW) model was calibrated for a four-year period from 2006 through 2009. The calibrated model was then applied to a 10-year period to better quantify the water-budget of a CSA compared to surrounding landforms. Results indicate that, depending on the degree (condition and thickness) or absence of capping sands used in reclamation, the CSA has one of two types of complex and integrated surface and shallow subsurface water flow systems. Where thicker capping sands exist there will be a perched and possibly rapidly responding water table. With minimal or non-existing capping there will be an interflow type shallow

subsurface flow system in relic desiccation cracks. The CSA studied was shown to restrict recharge to, and ET from, the underlying aquifer but exhibited higher surface flows and slightly lower surface ET than surrounding areas. Modeling results indicate CSAs with higher percentages of exposed overburden deposits will exhibit higher recharge and lower runoff responses than those with uniform clay placement.

Natural Channel Design of Low-Order Streams at Florida Phosphate Mines
AMEC, University of Florida

There is a great deal of public interest in protecting or restoring essential hydrological and ecological functions of streams. To obtain permits to mine, companies must provide reasonable assurance that streams, including headwaters, can be restored and that downstream areas will not be degraded. A fundamental component of restoration of stream function is that the channel shape and dimensions must be in dynamic equilibrium with the watershed. This project's main goal was to provide much needed information to enable designers to rapidly and accurately fit equilibrium channels to reclaimed basins. In addition, a stream classification system, based on hydrology, biology and geomorphology, was devised.

The final report "Peninsular Florida Stream Systems: Guidance for Their Classification and Restoration" is available on the Institute's website as FIPR Institute Publication No. 03-154-253. This project was performed to improve understanding of key physical and ecological attributes of natural streams in peninsular Florida in order to derive a practical process-based classification system; and also to provide design aids to assist with stream restoration in rural settings. Fifty-six of the best remaining stream systems in the peninsula were selected for monitoring of more than 120 quantitative variables known to associate with key stream system processes. The sites covered a wide range of physical gradients including soil drainage condition, drainage area, and valley slope, and were observed at watershed, valley, channel and patch scales. Hierarchical cluster analyses were conducted on the full dataset and various subsets to derive the classification groups. Variables were winnowed to a small group explaining the vast majority of stream variability using principal components analysis. The classification system defines streams based on their hydrobiogeomorphology (HBG) and is hierarchical: first categorizing an area based on watershed soil drainage conditions, then based on valley slope, and finally on channel and floodplain surfaces and their dimensions. Regional curve regressions were developed for use in natural channel design. Practical applications of the system for restoration design and construction are presented.



Stream Restoration.

Ongoing Projects

Screening of a New Candidate Biological Control Agent of Brazilian Peppertree University of Florida

Brazilian peppertree (*Schinus terebinthifolius*) is a non-native, highly invasive shrub or small tree that infests thousands of acres of mined and unmined lands in Florida. The plant is not invasive in its native habitat in South America, indicating that its aggressive spread in Florida and elsewhere may be due to escape from its natural enemies. This suggests that importing Brazilian peppertree's natural enemies, such as certain insects, may help control the plant. The research is testing the performance of a leaf-gall-forming psyllid insect on injuring Brazilian peppertree, testing the host specificity of the insect (attacking the target plant species but not harming other plant species), and developing methods for rearing the insects. This is information needed before the insect can be considered for release in Florida.



Life stages of Calophya terebinthifolii. The developing nymphs (lower left) induce the formation of open pit galls that are visible on the leaflets (Photo credits: Lindsey Christ and Marcelo Vitorino).

Establishment and Management of Vegetation Cover on Phosphogypsum Stacks

The initial research was conducted 1989-2004. The current project includes training of new industry personnel and consultants/contractors on the principles and methodology for establishing and managing vegetation cover on the side slopes of phosphogypsum stacks, plus evaluating and testing the effectiveness of additional techniques.



Vegetation on Phosphogypsum Stack.

Vegetation Management on Reclaimed Lands

We have been working closely with staff of the Department of Environmental Protection, Bureau of Mining and Minerals Regulation, to further develop methods and strategies for controlling invasive exotic vegetation and for replacing it with native plant communities or other more desirable and useful vegetation.



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Please contact us for more information on the research or programs of the FIPR Institute.