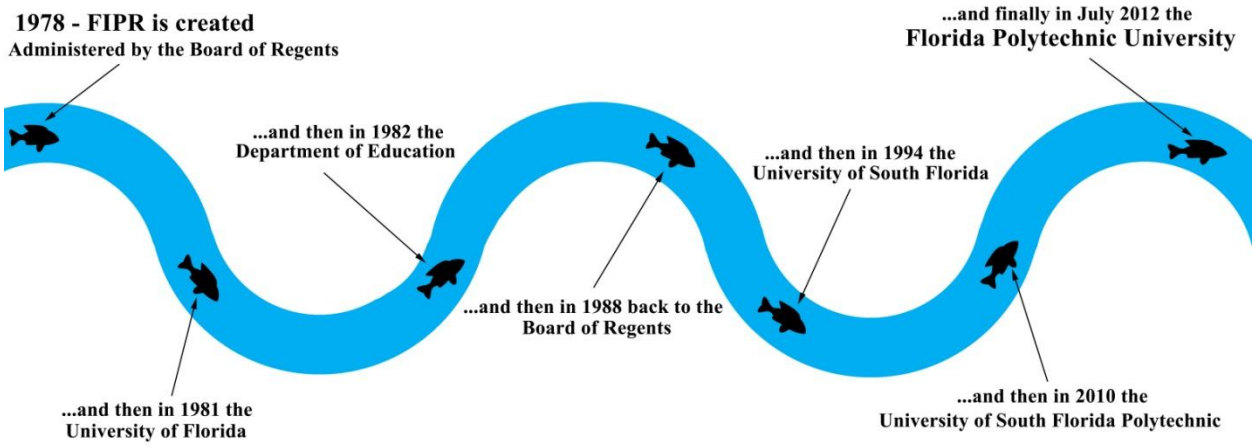
Fiscal Year 2012/2013 Annual Report

Florida Industrial and Phosphate Research Institute

FIPR Institute
Our Legacy Continues...



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Phosphate Research and Activities Board Members

Michael Daigle, The Mosaic Company

Herschel Morris, CF Industries, Inc.

Ann Paul, Audubon Florida

Vishwas Sathe, Florida Department of Environmental Protection, Tampa Office

*President, Florida Polytechnic University

* *Vacant at the end of this fiscal year*.

Florida Industrial and Phosphate Research Institute

Directorial Staff

Brian K. Birky, Ph.D., Interim Executive Director, and Research Director,

Public and Environmental Health

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

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

Vacant, Research Director, Chemical Processing

Gary Albarelli, Director of Information Programs

Karen J. Stewart, MLS, Library Director

Interim Executive Director's Message – 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 Legislature re-established The Florida Industrial and Phosphate Research Institute (FIPR Institute) within the University of South Florida Polytechnic and expanded its mission to enable work on related industries. 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 once again within this new university. Following the polytechnic model, the university will emphasize 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. The Institute's mission was expanded in the recent legislation to include industries other than the phosphate industry and to encourage commercialization of our research products and intellectual property.

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. Some of the Institute's research addresses solutions for process water, clay settling areas, phosphogypsum management, reclamation science, energy and water conservation, and resource recovery.

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 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. Research into techniques to rapidly dewater the clay is the key component to clay pond reclamation.

Active clay settling area.

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 radium in proportion to the amount of radium in the natural 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.

Phosphogypsum stack with process water.

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 groundwaters, 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. In addition, sulfuric acid production generates heat, which is used to generate power at the chemical processing site. The Institute has been investigating ways to recover much more energy from this process.

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.

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 also see Institute 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 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 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 the wealth of information we house. 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 phosphate that is mined.

Since the Institute's inception, 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.

Since 1978, the distribution to the Institute's trust fund has varied from 5% to 12.5% of the collected tax, and was 6.2% in fiscal year (FY) 2012-2013. The tax rate for FY 2012-2013 was $1.61 per ton severed. 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 FY 2012-2013

Trust Fund Balance

July 1, 2012	$8,527,768
June 30, 2013	$8,208,903

Operations

Income	
Gross Severance Tax[1]	$2,251,327.42
LESS Fees to Dept. of Revenue	($220,781.68)
Net Income	$2,030,545.74
PLUS Interest	$25,533.29

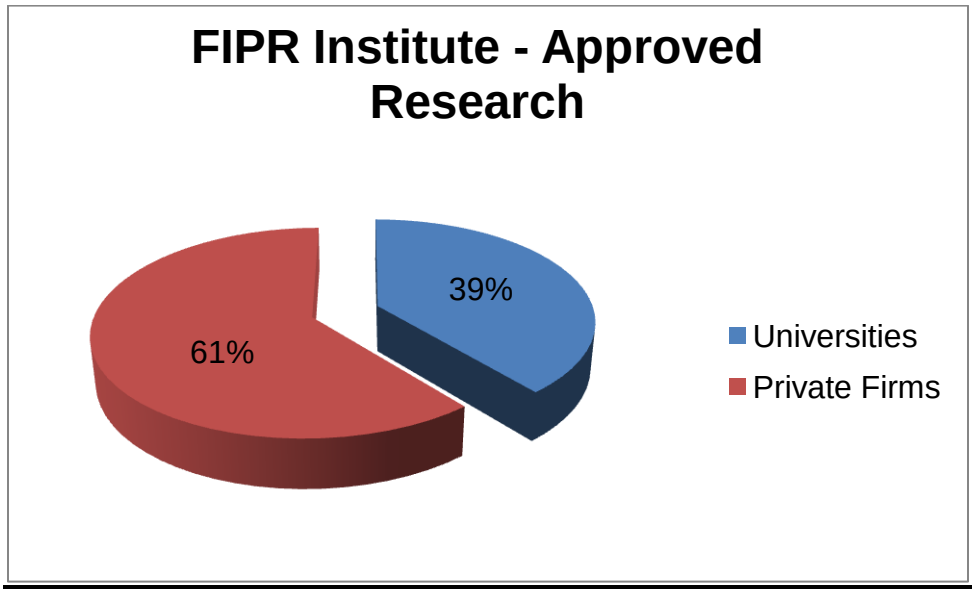
Fiscal Year 2012-2013 (continued)

Total Income	$2,056,079.03
Expenses	
Research	$625,143.04
Internal Operations[2]	$1,617,448.16
Education	$18,129.91

Library	$38,157.38
Laboratory	$76,064.31
<u>Total Expenses</u>	$2,374,942.80
Change in Trust Fund	($318,863.77)

[1]Per Section 211.3103, F.S. the severance tax rate was $1.61 per ton of rock severed from the earth. The FIPR Institute received 6.2% of the proceeds from the severance tax.

[2]"Internal Operations" includes staff salaries and benefits. The Institute's Research Directors and technicians (46% of the staff) spend most of their time directing or conducting research. Of the remaining staff, 33% deliver information and education services to the public and schools, and another 21% 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 research projects approved July 1, 2012 to June 30, 2013 by percentage of total funds awarded to universities versus private firms.

Auxiliary Funds (Not from the Severance Tax)

According to Florida Statutes 1004.346, the FIPR Institute may 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, 2012	$44,380.76
June 30, 2013	$84,786.47

Operations

Income	
Consulting Services	$43,375.00
Interest	$137.44
Total Income	$43,512.44
Expenses	
Supplies and Fees	$3,106.73
Change in Auxiliary Account	$40,405.71

Grants

The Institute's K-12 Education Program received funding from two grants from the Polk County School Board during this fiscal year. The funds were held in an account at the University of South Florida and the Institute invoiced against the account. The first grant was $24,000 and the second was $27,750. The Institute used $22,186.62 combined from the two grants during the fiscal year.

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.

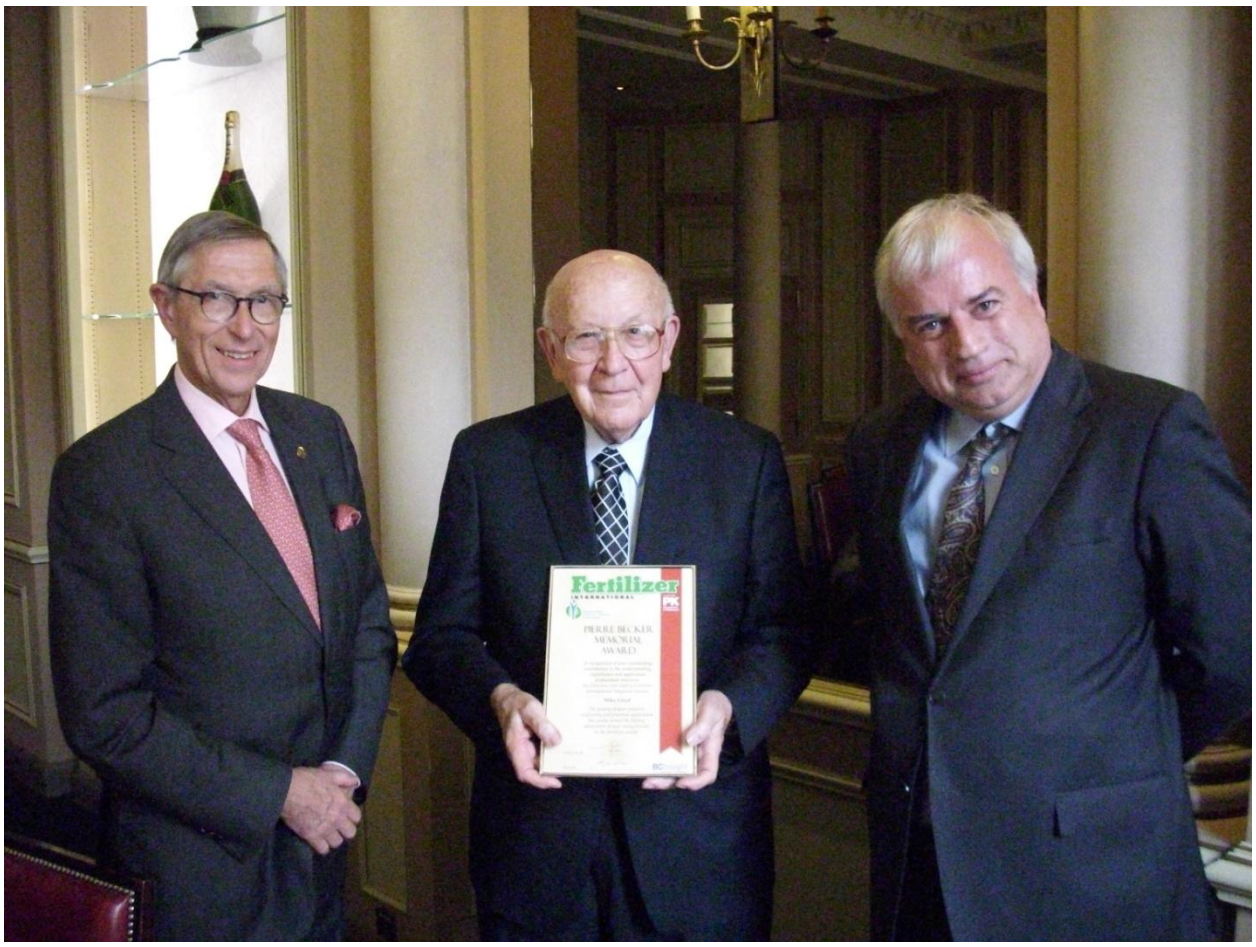
The Early Learning Coalition, the Polk County School Board, Business Networking International (BNI), and the Bartow Chamber of Commerce use the FIPR Institute Conference facilities for their regular weekly and monthly meetings.

The FIPR Institute is co-founder and supporter of the Annual Regional Phosphate Conference, which brings in over 500 attendees representing business, industry, academia and the state regulatory agencies.

Three of the Institute's employees, Shannon Medley, Marie Wilmot, and Aaron Medley, are graduates of Bartow Leadership Program and are active in the Bartow Chamber of Commerce.

- FIPR representatives provide information about the Institute and its connection with Florida Polytechnic University.
- Two staff members, Shannon Medley and Marie Wilmot, are Chamber Ambassadors who help recruit and retain chamber members and promote functions.
- Shannon Medley is on the Bartow Chamber Board of Directors and is Chair of the Bartow Leadership Alumni. She is also a Spirit of Bartow Award winner and graduate of Leadership Polk.

Awards and Achievements



Mike Lloyd (center) receives the Pierre Becker Memorial Award in Paris.

Mr. G. Michael Lloyd, the FIPR Institute's Director of Research Programs (retired) was recognized in the July/August issue of *Fertilizer International* as the recipient of the 2012 Pierre Becker Memorial Award. This prestigious award was presented on behalf of the magazine and the International Fertilizer Industry Association. Mike Lloyd's distinguished career in the business of phosphate fertilizer production has taken him through 6 decades of societal and technological change as well as the addition of billions of people to our worldwide population. Most people would mark their successes in terms of money saved in production improvements or earned in fertilizer sales, and certainly Mike has made significant contributions to the industry as a chemical engineer, process manager and director of scientific research. However, to assume that these accomplishments are the mark of this man would truly underestimate both his motives

and passion for what the fertilizer industry can do for mankind. Mike is driven by a fervent desire to end hunger wherever it may exist. He has often said that no child, anywhere, should ever go hungry. It should be no surprise that the staff and friends of the Florida Industrial and Phosphate Research Institute consider Mike to be our moral compass, and we are grateful to IFA and Fertilizer International Magazine for their recognition of his dedication with the Pierre Becker Memorial Award.

Dr. Patrick Zhang was appointed to the Editorial Board for Mineral Processing and Extractive Metallurgy Review journal. He was also named Honorary Chair for the Center for Comprehensive Utilization and Sustainable Development of Phosphate Resources, China University of Geosciences. Patrick is an Organizing Committee member for the 1st International Conference: Rare Earth Minerals/Metals – Sustainable Technologies for the Future, and Session Chair for the 7th International Conference on Rare Earths Development and Application.

Dr. Brian Birky is Convener of the NORM Task Force (Expert Panel) of the International Fertilizer Industry Association (IFA) Technical Committee. He is also a Technical Consultant (United States) to the International Atomic Energy Agency (IAEA). Brian served as Session Chair and Rapporteur for the 7th International Symposium on Naturally Occurring Radioactive Materials (NORM), Beijing, China.

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.

The FIPR Institute signed a Memorandum of Understanding with Aleff Group, Inc. (UK) and Paradeep Phosphates Limited (India) to work together to develop the mechanisms and processes that will promote and sustain collaborative efforts for safe, sustainable uses of phosphogypsum (PG), related research and development (R&D) on applied technologies, assessments of technology options, risks and economics and related regulatory and stakeholder issues.

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 expansion of research topics beyond phosphate into related areas will become incorporated into the Information Program work areas to support and reflect research activities. The Institute uses social media to share information about its activities and promotes the websites www.fipr.state.fl.us and www.floridapolytechnic.org.

The 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.

While the Summer Teacher Workshop remains the cornerstone of the K-12 Education Program, it 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, Institute 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 by the Institute's staff and community teachers.

The format of the Summer Teacher workshop, which has been conducted at the Institute since 1998, was changed from two weeks to one week to accommodate more Florida teachers. While core topics are still covered in the workshop, more in-depth investigation into topics is provided by one-day modules offered on Saturdays throughout the year. Teachers are able to attend any or all of the modules as their needs and schedule dictate.

The FIPR Institute Education program has also entered into a consulting partnership with the Polk County School System to utilize the Institute's expertise in helping the County implement new Science, Technology, Engineering and Math (STEM) programs into four elementary schools and one middle school as part of a federal STEM education grant to pilot STEM programs. Activities and lessons are developed by the Institute to enhance the STEM initiative in the State.

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

- The FIPR Institute mentored award winning science fair students in the community.
- The FIPR Institute Education Program is constantly visiting public and private schools throughout Florida and emphasizes STEM education.
- 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.
- Girl Scouts of West Central Florida – FIPR Institute coordinated a Council-wide Girl Scout STEM enrichment workshop – November 2012.
- 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
    - Phosphate Liaison between City of Mulberry and Mulberry High School in their community garden
    - Aquatics expert for Tampa Bay Regional Envirothon
    - Collaboration with Polk County schools as a STEM consultant.

Technical Exchange

Dr. Birky makes a presentation at an international conference in Beijing.

Annual Regional Phosphate Conference

The Annual Regional Phosphate Conference is held every October at the Lakeland Center. Many of the conference technical presentations, such as the following, are based on research conducted by or on behalf of our Institute.

- *Anionic Conditioning of Phosphate Flotation Feed:* Glenn Gruber, Jacobs Engineering, Inc.
- *Clay Slurry to Paste – A Deep Cone Thickener Pilot and Economics Study*: John Ellington, PENN PRO, Inc. and Leon Seale, AMEC Environmental and Infrastructure

- *JDCPhosphate – Improved Hard Process Overview and Demonstration Plant Construction Progress:* Tip Fowler and John Demaske, JDCPhosphate, Inc. (FIPR did not fund, but was consulted)
- *Gas Turbine Topping to Enhance Energy Production in Sulfuric Acid Manufacture*: Richard Davis, Davis & Associates Consulting, Inc. (FIPR funded the analysis)
- *Management of Nuisance and Exotic Vegetation on Mined Lands in Florida: A Guidance Manual:* Steve Richardson, FIPR Institute and Ed Murawski, Kleinfelder
- *Using Reclaimed Phosphate Lands for Water Treatment and Aquifer Recharge*: Adam Platt, CF Industries, Inc. (extension of FIPR funded research)
- *Hydrological Connectivity of Clay Settling Areas and Surrounding Landscapes:* Mark Ross, USF (extension of FIPR funded research)
- *Application of SCI/Habitat Assessments as Outcome Measures for Reclaimed Stream Function*: John Kiefer and Jessie Taft, AMEC Environmental and Infrastructure (extension of FIPR funded research)
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Direct FIPR Institute Staff Tech Transfer

FIPR Institute staff members have been actively involved in technical exchange at various forums during the last several years, as highlighted below:

- P. Zhang. 2012. “Recovery of Critical Elements from Florida Phosphate: Phase I. Characterization of Rare Earth Elements”. Presented at *The 1st International Conference: Rare Earth Minerals/Metals – Sustainable Technologies for the Future*. August 12-17, California, USA.
- P. Zhang, 2012. “Rare Earth Elements in Florida Phosphate.” Presented at the *Regional Workshop on Uranium Resources Assessment and Recovery from Phosphate and Rare Earth Element Ores*. June 17-21. Cairo, Egypt.
- P. Zhang, 2012. “Uranium Recovery from Phosphoric Acid: The Florida Experiences” Presented at the *Regional Workshop on Uranium Resources Assessment and Recovery from Phosphate and Rare Earth Element Ores*. June 17-21. Cairo, Egypt.
- P. Zhang, 2012. “Sustainable, Comprehensive Utilization of Phosphate Resources” Presented at the *Regional Workshop on Uranium Resources Assessment and Recovery from Phosphate and Rare Earth Element Ores*. June 17-21. Cairo, Egypt.

- P. Zhang. 2012. “Rare Earth Extraction: Update and Flow Sheet Opportunities”. Presented at the *International Atomic Energy Agency Technical Meeting: Uranium Production from Phosphate Rocks*. April 16-20, Vienna, Austria.
- S. Richardson. Presented FIPR Institute research findings on management of the non-native invasive grass, cogongrass, at the Cogongrass Round Table, Myakka River State Park, September 26, 2012.
- S. Richardson. “Guidelines for management of nuisance and exotic vegetation”. Regional Phosphate Conference October 10-11, 2012, Lakeland, FL.
- B. Birky. “Overview of Industrial NORM in the USA with Emphasis on the Phosphate Industry”, 7th International Symposium on Naturally Occurring Radioactive Materials (NORM), Beijing, April 2013.
- J. Hilton, B. Birky, and M. Moussaid. “Comprehensive Extraction, a Key Requirement for Social Licensing of NORM Industries?”, 7th International Symposium on Naturally Occurring Radioactive Materials (NORM), Beijing, April 2013.
- P. Zhang, 2013, “Comprehensive Recovery and Sustainable Development of Phosphate Resources”, Keynote speech at 2nd International Symposium on Innovation and Technology in the Phosphate Industry (SYMPHOS 2013), Agadir, Morocco, May 6-11, 2013.
- P. Zhang, 2013. “Wet-Process Phosphoric Acid Production: Technologies and Comprehensive Resource Recovery”. Presented at the United Nations – IAEA Expert Review Meeting on Uranium Production from Phosphate Rocks. IAEA Headquarters, Vienna, March 25-28, 2013.
- P. Zhang, R. Stana, H. El-shall, and B. Moudgil, 2013. “A Review of Industrial Innovations in Phosphate Processing”. Presented at the 2013 SME Annual Meeting, Denver, CO, February 24-27, 2013.
- P. Zhang, 2013. “Uranium Recovery from Phosphoric Acid”, Lecture at the United Nations-IAEA International Training Course: Performance Optimization in Uranium and REE Production from Phosphate Rocks, Tunis & Gabes, February 11-15, 2013.
- P. Zhang, 2013. “Rare Earth Elements (REE) in Florida Phosphate: Characterization and Recovery Approaches”, Lecture at the United Nations-IAEA International Training Course: Performance Optimization in Uranium and REE Production from Phosphate Rocks, Tunis & Gabes, February 11-15, 2013.
- P. Zhang, 2013. “Sustainable Development of Phosphate Resources: Challenges & Opportunities”. Lecture at the United Nations-IAEA International Training Course: Performance Optimization in Uranium and REE Production from Phosphate Rocks, Tunis & Gabes, February 11-15, 2013.
- P. Zhang, 2012. “Uranium Recovery from Phosphoric Acid: The Florida Experiences” Presented at the *Regional Workshop on Uranium Resources*

Assessment and Recovery from Phosphate and Rare Earth Element Ores. June 17-21. Cairo, Egypt.

- P. Zhang, 2012. "Sustainable, Comprehensive Utilization of Phosphate Resources" Presented at the *Regional Workshop on Uranium Resources Assessment and Recovery from Phosphate and Rare Earth Element Ores*. June 17-21. Cairo, Egypt.
- P. Zhang. 2012. "Rare Earth Extraction: Update and Flow Sheet Opportunities". Presented at the *International Atomic Energy Agency Technical Meeting: Uranium Production from Phosphate Rocks*. April 16-20, Vienna, Austria.

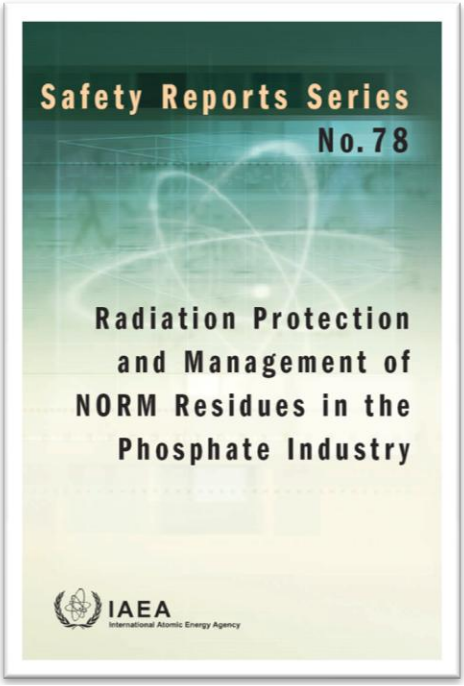
Recent FIPR Institute Publications

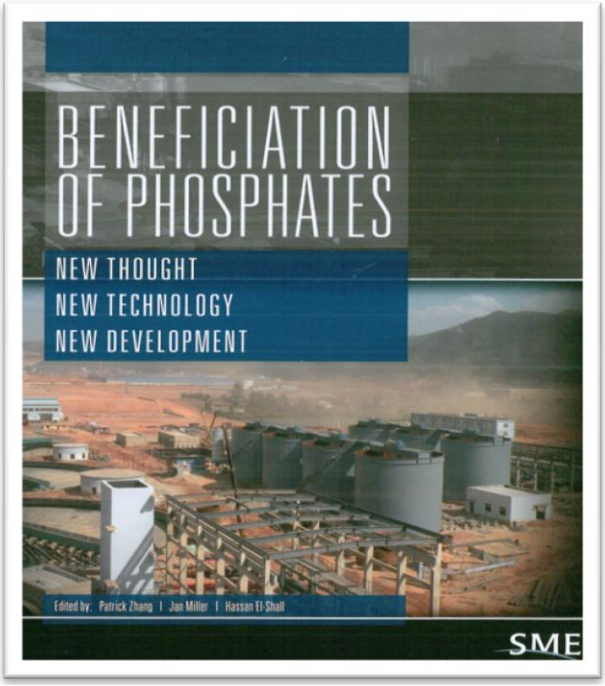
(Available at: http://www1.fipr.state.fl.us/Publications)

- FIPR Institute Publication No. 02-179-246. **"**Development of Reagent Schemes for Reducing MgO Content in the Flotation Concentrate for Processing Florida's High-Dolomite Phosphate Deposits". Patrick Zhang, Florida Industrial and Phosphate Research Institute; Shibo Zheng, Wenyi Sun, and Xiaoqing Ma, China Bluestar Lehigh Engineering Corporation; Jan Miller, University of Utah. September 2012.
- FIPR Institute Publication No. 03-160-248. **"**Management of Nuisance and Exotic Vegetation on Phosphate Mined Lands in Florida". Steven G. Richardson, Florida Industrial and Phosphate Research Institute; Edward Murawski, Kleinfelder. September 2012.
- FIPR Institute Publication No. 03-157-249. **"**Control and Management of Cogongrass and other Exotic Grasses on Disturbed Lands in Florida: Research Report". Dr. Steven G. Richardson, Florida Industrial and Phosphate Research Institute. May 2013.

Other Publications by FIPR Institute Staff

- International Atomic Energy Agency (IAEA). "Safety Reports Series No. 78 Radiation Protection and Management of NORM Residues in the Phosphate Industry", Vienna, 2013 (B. Birky acknowledged as key contributor). *http://www-pub.iaea.org/MTCD/publications/PDF/Pub1582_web.pdf*





- P. Zhang, J. Miller and H. El-Shall, editors, 2012, Beneficiation of Phosphates: New Thought, New Technology, New Development, Society for Mining, Metallurgy, and Exploration, Inc., Englewood, Colorado, 2012.
- P. Zhang and R. Stana, 2012, “Phosphogypsum Management and Utilization: A Review of Research and Industry Practice”, in Beneficiation of Phosphates: New Thought, New Technology, New Development, Society for Mining, Metallurgy, and Exploration, Inc., Englewood, Colorado, pp. 309-322.
- J.D. Miller, C.L. Lin, I. Ahmed, X. Wang, and P. Zhang, “Advanced Instrumentation for Mineral Liberation Analysis and Use in the Phosphate Industry”, in Beneficiation of Phosphates: New Thought, New Technology, New Development, Society for Mining, Metallurgy, and Exploration, Inc., Englewood, Colorado, pp. 309-322.
- Y. Han, L. Liu, Z. Yuan and Z. Wang, P. Zhang, 2012, **“**Characteristics Comparison of Low-grade Hematite Products in High Pressure Grinding Roller and Jaw Crusher,” *Minerals & Metallurgical Processing Journal*, Vol. 29 (5).
- P. Zhang, 2012, “Recent Technological Breakthroughs in Phosphate Processing,” *Mineral & Metallurgical Processing Journal*. Vol. 29 (1), pp. 36-46.

Research Areas

Projects were funded from the Phosphate Research Trust Fund and managed by the FIPR Institute. Some projects were conducted in-house while many were 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 adopted on February 17, 2011. It discusses goals and approaches to achieving 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

Development of Reagent Schemes for Reducing MgO Content in the Flotation Concentrate for Processing Florida's High-Dolomite Phosphate Deposits

FIPR

A 1989 FIPR study of the future phosphate resources in Florida showed that the ratio of concentrate to pebble would become higher and higher. Therefore, reducing MgO content in the concentrate by a small margin would allow blending of a large portion of the high-dolomite pebble. A rough estimate based on the study indicated that about 90% of the high-dolomite pebbles could be used, if the MgO content in the concentrate is reduced by 30%.

The above rationale prompted FIPR to conduct this in-house project. The project, conducted in collaboration with China Bluestar Lehigh Engineering Corporation, was designed to develop techniques to reduce MgO content in the concentrate with minor modifications or no change to the current processing flowsheet. The ideal way of doing this is to depress dolomite while floating phosphate, but the following 6 approaches were tested under this project: 1) adding a dolomite depressant in the rougher flotation step; 2) dolomite flotation on the rougher concentrate with and without grinding; 3) dolomite flotation on the cleaner concentrate with and without grinding; 4) scrubbing the flotation feed; 5) scrubbing the rougher concentrate; and 6) scrubbing the cleaner concentrate.

Successful methods include adding a dolomite depressant in the rougher flotation step, dolomite flotation on the cleaner concentrate with grinding, and scrubbing the cleaner concentrate in quartz sand. These techniques could reduce MgO content in the final concentrate by over 20%. The flotation process could achieve a concentrate with the lowest MgO content, but it is the most expensive approach. Adding a dolomite is inexpensive and easy, but the effect is limited. Overall, scrubbing of the final concentrate may be the most promising technology for this purpose.

New Mobile Pre-processing Equipment for Florida Phosphate Mining

Haver Engineering

Typical rock disaggregation using high-pressure water from pit guns.

In the current phosphate mining practice in Florida, a dragline digs out the matrix and dumps it in a pit where high-pressure water guns are used to break down the large clay balls and create slurry that is pumped to the beneficiation plant. This practice has the following drawbacks:

1. A lot of energy is wasted because of the long distance between the hydraulic guns and the matrix.
2. Hydraulic energy is dissipated when it strikes the pool of water at the point of impact.
3. In travelling the long distance, water velocity from the water jet decreases.
4. Use of large amounts of water restricts pumping to lower than ideal percent solids thus limiting energy savings.

Haver Engineering of Germany has completed the FIPR-funded project to design and evaluate a new mobile pre-processing system for Florida phosphate mining. The goal of this project was to reduce energy and water use for phosphate mining by disaggregating phosphate ore (matrix) more efficiently than the current practice and enabling pumping at higher solids content for matrix transportation from the mine to the

beneficiation plant. The new system is a hammer mill based mobile washer, with its major benefits shown in Table 1.

Table 1. Comparison of the New Mobile Washer to Current Industry Practice.

Item	Current System	Mobile Washer
Energy use for slurrying	1.32 kWh/ton	0.36 kWh/ton
Water requirement	570 gallon/ton	26.4 gallon/ton
Percent solids	30-35%	60%
Energy use for pumping	0.46 kWh/ton-mile	0.23 kWh/ton-mile

Although the practicality of the new system remains to be investigated, the potential benefits are intriguing.

Ongoing Projects

Innovative RTS Technology for Efficient Separation of Dolomite from Phosphate
University of Kentucky

The goal of this project is to develop and evaluate an innovative high efficiency triboelectrostatic separation technology, referred to as a rotary triboelectrostatic separator (RTS), for beneficiation of dolomitic phosphate samples without use of any chemicals or water. The RTS technology is based on differential surface charge acquired between phosphate and gangue minerals such as dolomite and quartz upon their mutual contacts or frictions with a charging medium or charger. This allows separation in an external electric field resulting from different motion trajectories for different particles.

The RTS technology has been well demonstrated for effective rejection of siliceous impurities from phosphate. For example, it upgraded a raw phosphate feed to a 30% P_2O_5 concentrate with about 90% P_2O_5 recovery and 90% acid insoluble rejection in one stage. Recent fundamental studies have strongly indicated that this technology will be more effective for separating dolomite from phosphate.

Parametric and statistically designed dolomitic phosphate separation tests will be performed using the RTS separator to investigate the effects of various process variables, their interactions, and optimum conditions for achieving the most efficient separation of dolomite from phosphate. Phosphate pebble contains the highest dolomite content, but if the dolomite content in flotation concentrate can be reduced to 0.5-0.6%, the pebble may be blended with the flotation concentrate to produce a final product with less than 1% dolomite. Both pebble (after grinding to -250 µm) and flotation

concentrate will be tested in the project and a better approach will be recommended after comparative data analysis.

Recovery of Rare Earth Elements from Florida Phosphate

FIPR

As part of our effort to promote comprehensive uses and sustainable development of Florida phosphate resources, the FIPR Institute started exploring the recovery of rare earth elements (REE) from phosphate. These elements have very specific, critical uses in a multitude of markets. For example, lanthanum is used as a catalyst in breaking down crude oil to produce gasoline, diesel and jet fuel; neodymium is the core magnetic component in high-strength magnets for electric car batteries, wind turbines and hard disk drives; and cerium oxide is an important component of glass polishing powders. Rare earths are also essential for many military applications. Many of these applications have no substitute materials and the move to green technologies has dramatically increased their demand. The first phase of our effort is to characterize REE occurrence in the phosphate ore and various processing streams.

The analytical method for REE adopted/developed by the FIPR Institute is reliable. Preliminary conclusions from the ongoing project include the following: (1) appreciable amounts of REE are present in the currently mined Florida phosphate; (2) the highest REE concentrations are found in a flotation concentrate analyzing over 900 ppm; and (3) REE are mainly associated with francolite (the phosphate mineral) and are concentrated in the fine particles. This project has enhanced the capabilities of the FIPR Institute analytical lab, laying a sound foundation for our future research on extraction of REE from phosphate.

According to a recent USGS estimate, the world's total REE reserves amount to 110 million tons of REE oxides. REE in phosphate deposits averages roughly 300 ppm of REE oxides, which translates to 87 million tons based on the recent estimate of 290,000 million tons of world phosphate resources. This indicates that there is nearly as much REE in phosphate as in REE minerals. Following a successful characterization of REE in currently mined Florida phosphate, FIPR initiated a major research project to recover REE from various streams of phosphate mining and processing, including waste clay, amine flotation tails, concentrate, phosphoric acid and phosphogypsum. Initial promising results have been achieved from concentrating REE-containing minerals in amine tails using a simple gravity separation device.

Gravity separation shaking table (donated by Mosaic) for concentrating REE-containing minerals.

Projects Funded This Fiscal Year

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

University of Utah

This research will 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. 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.

Remote Real-time Industrialized Analyzer of Phosphate Rock

R Squared S, Inc.

Field testing the remote LIBS analyzer at the mine face.

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 for wet minerals using the laser-induced breakdown spectroscopy (LIBS) technology.

The FIPR Institute and the Israeli research team have also long set the goal of developing a LIBS-based analyzer for remote analysis of ores and overburden before these materials are dug out or in transit to the beneficiation plant. 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.

Under phase I of the remote LIBS research 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 drag line 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.

Recognizing the great potential of this technology for improving both mining and beneficiation efficiency, FIPR and LDS have recently agreed to co-fund a project to design and test an industrialized remote LIBS analyzer.

Chemical Processing

Ongoing Projects

Progress in chemical processing research was hampered by both the vacancy of the Research Director's position and a lack of unsolicited proposals. The vacant position will be filled when the transition to Florida Polytechnic University is complete. Nevertheless, progress has been made in fulfillment of the Institute's mission.

Process Water

Process water is used to transport phosphogypsum slurry to the stack, as make-up water for phosphoric acid manufacture, to carry away heat generated in the plant, and to scrub exhaust gases to prevent the discharge of undesirable compounds to the atmosphere.

The process water becomes acidic during its use and contains materials found in both the phosphate rock and the sulfuric acid. While the plants are designed to operate with a negative water balance, periods of excessive rainfall may make it necessary to treat and discharge surplus water.

Typical treatment involves two-stage neutralization with lime to remove fluoride and phosphate, followed by aeration to remove ammonia, then the addition of sulfuric acid to reduce the pH to 6-7. Even after treatment, the conductivity of the treated water is higher than allowed and fresh water must be added before it can be discharged to the surface waters of the state.

Finding or developing a technology that would significantly remove any or all of the soluble salts, or raise the pH of the process water economically, would be desirable. Many private companies and other researchers are developing water treatment technologies for a variety of applications. Some of these technologies may be effective and economical for process water treatment. The Institute has held meetings and has shared information with some of these companies to evaluate their processes and products. A Process Water Technical Advisory Committee Meeting was held to transfer some of this new information to the phosphate producers. These efforts will continue and researchers are encouraged to submit proposals for funding if specific phosphate industry research is required.

Phosphogypsum

Over 1.3 billion tons of phosphogypsum (PG) are stacked in Florida and about 28 million more tons are added each year. The stacks must be maintained during use and after closure, and occupy potentially valuable real estate. This unwanted legacy has the potential to become a major asset. Safe and beneficial use of this form of gypsum could improve the environment, economy, and welfare of the citizens of the state. Research has demonstrated that using phosphogypsum in both road-building and agriculture offers substantial economic benefits without creating excessive risks. Other uses that are environmentally and/or economically desirable are also possible. Since regulatory restrictions to date will make it very difficult to use all of the stockpiled phosphogypsum, even if those restrictions are significantly relaxed in the future, it is desirable to find methods which will reduce its rate of production.

The Institute has continued to accumulate factual information on actual risks and economic benefits of various uses of phosphogypsum. The results of this international effort are prominently featured in the recently published International Atomic Energy Agency (IAEA) Safety Report on the phosphate industry, with substantial FIPR Institute participation. Many practical uses of phosphogypsum have now been documented with evidence of safe practices and economic success. According to the IAEA, “As a co-product, or residue, PG is not a *de facto* “waste,” as currently defined in some jurisdictions, nor does it meet the legal definition of waste in that it has a history of safe use. Based on known published and peer-reviewed evidence, PG has a wide variety of safe, beneficial options for use, assuming that the instructions for use and known good practices are correctly followed.”

In addition to development of PG uses, we continue to work with researchers to develop economically alternative phosphoric acid manufacturing technologies to reduce or eliminate PG production.

Public & Environmental Health

Completed Projects

Impact of Phosphate Fertilizer, Phosphoric Acid and Animal Feed Production Processes on Levels of Hazardous Air Pollutants and Their Distribution along Production Pathways

University of Florida

Emissions of Hazardous Air Pollutants (HAPs) from phosphate fertilizer manufacturing facilities may potentially lead to health effects in exposed populations. In central Florida, there are several phosphate fertilizer manufacturing plants that are potential sources for HAPs.

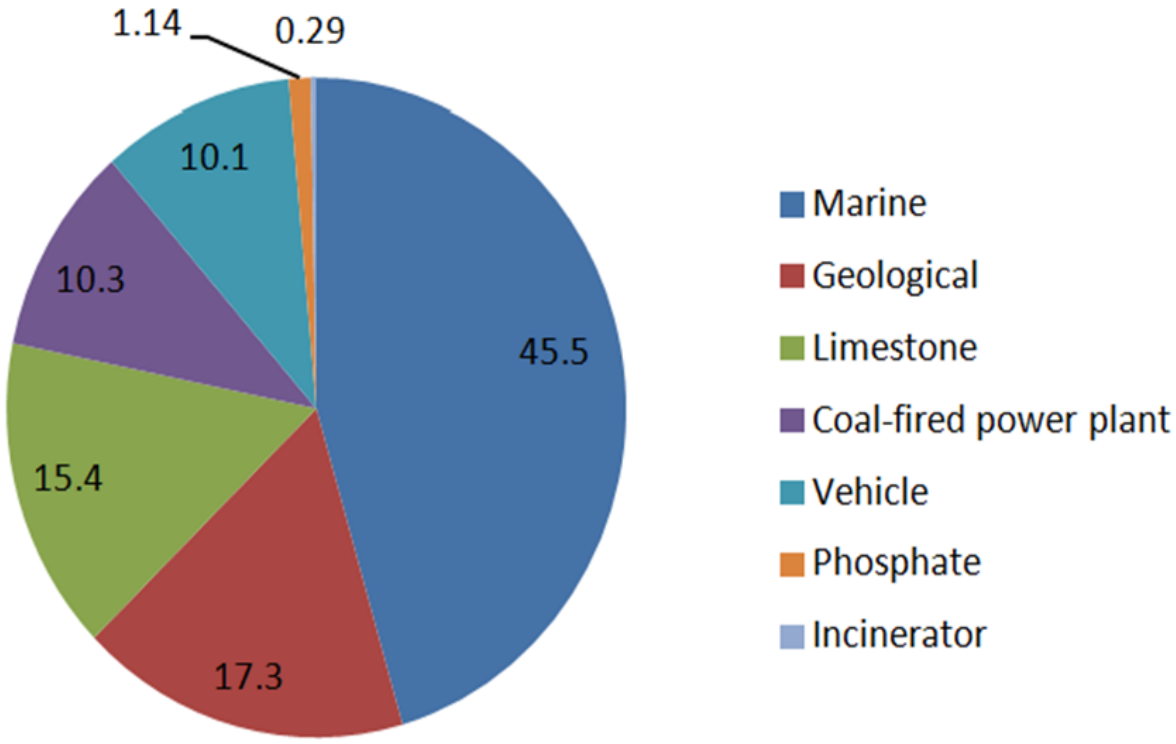
The AERMOD dispersion model was applied to calculate downwind concentrations using meteorological data in the vicinity of processing plants. Emission profiles of trace metals in particulate matter from stack flue gas of phosphate fertilizer plants were used to calculate ground level concentrations. Six receptors were chosen for the assessment, including four urban areas and two ambient air monitoring sites.

The chemical mass balance (CMB) air quality model was used to both identify the presence of and to quantify source contributions to receptor concentration. The Human exposure model-3 (HEM3) was used to estimate human exposures and health risks.

Among the six receptors, the highest annual ground level concentration of Pb was 13.3 pg/m^3 (211 pg/m^3 as a daily peak) that was much lower than the National Ambient Air Quality Standard (150 ng/m^3). There are no specific USEPA standards for Ni and Cr. The highest values (10.8 and 4.93 pg/m^3) are lower than European Communities limit values (10-50 ng/m^3; 5.0 ng/m^3) .

The dominant trace metal contributors are marine sources, geological sources, lime use, and power plants. The phosphate fertilizer plants only contributed around 1.14-1.93%. The Cr species contributions by phosphate processing facilities were 13.6% and 19.9% at the ambient locations and even lower in the urban settings.

The maximum cancer risk for Cr was slightly above what is normally accepted as negligible ($1x10^{-6}$). However, no residential exposures occurred at these levels. The risks for all other metals were negligible. The various metals have different health effects as measured against the Developmental HI (hazard index), Respiratory HI, and Kidney HI, but all of them are well below 1.00, which means the levels are safe.



Percentage contributions by different sources to metal concentrations at a receptor location in the phosphate processing region.

Ongoing Projects

Statistical and Spatial Analysis of Pre- and Post-Mining Radiological Data
Cardno ENTRIX

The FL Dept. of Health (FLDOH), Bureau of Radiation Control (BRC) has a pre- and post-mining survey program which has compiled thousands of measurements over more than 20 years. Many land parcels have been evaluated over the years and it is desirable to display their individual characteristics. This project will provide a statistical analysis of the FLDOH pre- and post-mining data set. Maps of the mined and reclaimed lands will display radiological data so that mining impacts can be easily identified and interpreted by both researchers and members of the public.

Statistical descriptions will be generated for:

- Exposure rate in µR/h,
- Soil radon exhalation in pCi/m^2-s,
- Soil ^{226}Ra in 1-ft core sections to 6 feet in pCi/g,

- Ambient air radon by alpha track in pCi/L,
- Ambient air exposure rate (quarterly average) by TLD in µR/h, and
- Surface and groundwater data for ^{226}Ra, ^{228}Ra, U and ^{210}Po in pCi/L

Exposure rate measured at the ground surface.

Projects Funded This Fiscal Year

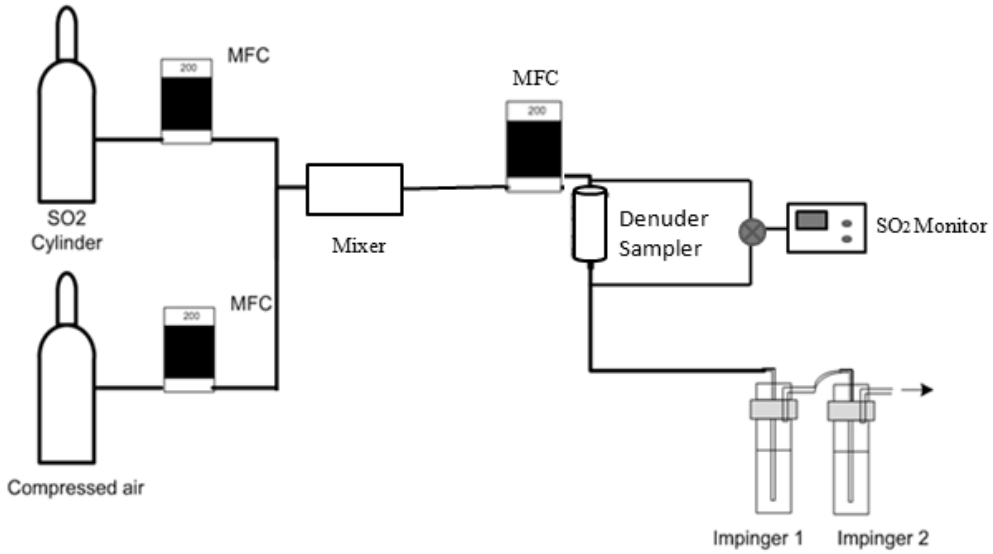
Commercial Development and Validation of a Disposable Personal Sampler for Inorganic Acid Mist Measurement

University of Florida

This research was 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.



Experimental setup for testing aerosol collection efficiency and particle loss.

Reclamation

Completed Projects

Guidance Manual for Control and Management of Nuisance and Exotic Vegetation on Reclaimed Lands

FIPR / LPG Environmental

The FIPR Institute and other university researchers have conducted extensive research on controlling many exotic and nuisance weeds, as well as methods for native plant establishment and for habitat management. In addition, land managers for various government agencies and non-profit organizations, plus mining industry reclamation personnel, have tried a number of approaches for controlling weeds and restoring native vegetation communities. This information is has been compiled and distilled into a manual to guide practitioners toward successful management of nuisance and exotic plants and the reestablishment or restoration of native vegetation communities.

Improving Weed Control for Native Plant Community Establishment and Restoration

FIPR

Invasive exotic plants are major problems on disturbed lands, such as reclaimed mined lands, but also in natural areas in Florida. The control of exotic nuisance plants is a major contributor to reclamation, restoration and management costs in natural areas and on disturbed lands. The purpose of this research was to develop and evaluate cost effective weed control strategies to enhance establishment and growth of native plants on reclaimed phosphate mined lands and to restore natural areas infested with exotic weeds. The research included studies of competitive interactions with native plants, improving the effectiveness and efficiency of herbicides for control, and selective herbicidal control of weeds (including native plant tolerances to herbicides). The project developed guidelines and recommendations for managing invasive exotic plants.

Cogongrass infestation on reclaimed mined land.

Herbicide treatment of cogongrass on reclaimed mined land.

Ongoing 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, there were still uncertainties in making accurate estimates of evapotranspiration and ground water seepage. This project is evaluating and modeling the complete water balance of a CSA and includes methodology for more accurate determination of evapotranspiration and ground water seepage. One interesting finding has been 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.

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 aims to provide much needed information to enable designers to rapidly and accurately fit equilibrium channels to reclaimed basins.

Stream construction.

Projects Funded This Fiscal Year

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

The method under investigation for control of Brazilian peppertree involves two insects (i.e., two species of the same genus). The researchers have learned that the first insect attacks one genotype of the tree more strongly than the other genotype, but the second insect appears to attack both genotypes and hybrids. The researchers are thus focusing more on the second insect.

Brazilian peppertree.

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