Fiscal Year 2016/2017 Annual Report

Florida Industrial and Phosphate Research Institute

Phosphate Chemical Processing Site

Approved by the Florida Polytechnic University Board of Trustees

September 13, 2017

Approved by the Phosphate Research and Activities Board

September 15, 2017

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Phosphate Research and Activities Board Members

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Terrence Baker, PCS Phosphates

Jeffrey Narrow, The Mosaic Company, Vice-Chairman

Mark Rachal, Audubon Florida

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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

Executive Director's Message – Dr. Brian Birky

After over three decades of service as a state agency, the Florida Industrial and Phosphate Research Institute was re-established within Florida Polytechnic University in 2012. Since that time, the Institute has integrated its administrative functions, library services, and K-12 STEM Education Program within the University. The Institute is currently focusing on cooperative research projects involving University faculty and students, which will be ready for inclusion in the FY 17/18 Annual Report.

In this report, we describe the Institute's financial condition, community and business engagement, awards and achievements, information program, technical exchange, and research.

The Institute's financial condition is fairly stable, but is characterized by fluctuations up to hundreds of thousands of dollars per year. The Institute experienced a decline in the Trust Fund balance this year, but remained within its budget.

The Institute's staff is active in the community through organizations such as Florida Ag in the Classroom, Bartow Chamber of Commerce and its Leadership Program, Leadership Polk, Bartow Community Healthcare Foundation, Girls Incorporated, Polk Vision's Building a Healthier Polk, Girl Scouts of West Central Florida, and others.

Staff members serve on Boards and Expert Working Groups, as Honorary Chairs of conferences and universities, and as Science Fair Judges locally and internationally.

The Institute's library is open to the public, and contains both print and electronic resources. The in-house collection is largely phosphate-related, but there are broader scientific publications and periodicals, especially in energy and chemical engineering disciplines. In addition, the library is connected to other libraries of the state university system through Florida Polytechnic University.

The Education Program is fully integrated within the University's Community Outreach Program. STEM lessons developed at FIPR are used in the program to engage students and prepare them for further education and careers in high-tech fields.

The Institute, most notably through its Directors, continued to exchange technical information with other scientists and the public via workshops, conferences, publications, and presentations. An exception to the typical information pathways was a spike in the number of press interviews this year. This is directly attributable to two events of environmental and social significance.

The first event was a sinkhole that opened under a cell within an active phosphogypsum stack. 215 million gallons of process water held in the cell breached a synthetic liner and spilled into the Upper Floridan Aquifer. This water moves slowly and pumping seems to have contained the plume. Extensive on-site monitoring and off-site testing of wells used for drinking water continues as the sinkhole is plugged and sealed. In the weeks following the event, FIPR's role was to provide general information about stacks, water characteristics, and public health.

The second event was a lawsuit filed on behalf of plaintiffs living in two Lakeland communities that were built on reclaimed, formerly mined lands. The main public health concern was exposure to external irradiation due to naturally occurring radioactive materials (NORM). The Florida Department of Health, Bureau of Radiation Control responded with extensive gamma radiation surveys of the communities and in-house measurements on request. FIPR's role was to put the radiation levels, potential human doses, and risk in perspective. As such, this is mainly a matter of public education, but also reinforces the position that special care must be taken to remediate land intended for residential development such that radiation is reduced to acceptable levels, and that housing construction is optimized to keep radon concentrations to <4 pCi/L (picocuries per liter) of air with a preferred level of <2 pCi/L (USEPA).

While the broad areas of research have remained the same, specific topics of interest change as needed. Mining, beneficiation, chemical processing, land reclamation, and public and environmental health remain focal areas for research. Incidents like those mentioned previously may spawn new research, or evaluation of existing technology, in microseismology, sensors to detect liner breaches, sensors that can withstand extreme pressure and exposure to acid, and more.

However, our main drivers continue to be sustainability, comprehensive extraction, and critical materials. These drivers were discussed in detail in last year's report. Social, economic, and environmental components are inherent to sustainability. The social license to operate is key to how industry responds to events such as those that occurred this year, and how the public judges that response.

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 5.6% for this fiscal year, and the tax rate was $1.80 per ton of rock severed.

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, 2016	$7,873,182
June 30, 2017	$7,563,064
Operations	
Income	
Gross Severance Tax[1]	$1,768,280
LESS Fees to Dept. of Revenue	($113,407)
Net Income	$1,654,873
PLUS Interest	$113,908
Total Income	$1,768,781
Expenses	
Research	($347,690
Internal Operations[2]	($1,731,209)
Total Expenses	($2,078,899)
Change in Trust Fund	($310,118)

[1]Per Section 211.3103, F.S.

[2]"Internal Operations" includes staff salaries and benefits, and expenses for the Education Program, Library, and Laboratories. The Institute's Research Directors and technicians spend most of their time directing or conducting research. The remaining staff deliver information and education services to the public and schools, or provide office 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.

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, 2016	$601,208
June 30, 2017	$677,501
Income	
Consulting	$68,439
PLUS Interest	$9,236
Total Income	$77,675
Total Expenses	($1,382)
Change in Auxiliary Account	$76,293

Awards and Grants (Not from the Severance Tax)

Critical Materials Institute (CMI) Account

Revenue	$166,598
Expenses	($166,598)
Change in CMI Account	$0

Florida Wildflower Foundation (FWF)

Revenue	$3,593
Expenses	($2,875)
Change in FWF Account	$718[1]

[1]The remaining funds were approved as carry over for additional research.

The overall financial status for FY 2016-2017, which combines the Trust and the Auxiliary Funds, was $8,474,390 as of July 1, 2016. The final amount, as of June 30, 2017, is $8,240,565; showing a net decrease of $233,825.

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, and the Bartow Chamber of Commerce use the FIPR Institute Conference facilities regularly for their meetings. Finally, the Institute's employees are active in the community and serve on various committees and boards.

- Gary Albarelli
  - Serves on the Board of Directors of Florida Ag in the Classroom
- Shannon Medley
  - Served on the Bartow Chamber of Commerce Board of Directors Executive Committee as Vice President of Public Affairs until December 2016
  - Chairs the Bartow Chamber's Leadership Bartow Program; completed year 1 of 2
  - Chairs Leadership Bartow Leadership Alumni Committee
  - Serves on the Board of Directors for the Bartow Community Healthcare Foundation
- Marie Wilmot
  - Graduate of both Bartow Chamber of Commerce Leadership and Leadership Polk
  - Serves on Girls Incorporated Board of Directors
  - Serves on Polk Vision's *Building a Healthier Polk* Alignment Team
  - Instructor at the Lake Wales YMCA and volunteers as an instructor at other community outreach facilities and events
    - Lakeland Coleman Bush Community Center
    - Bartow Carver Recreational Center
    - Polk County School Board Employee Wellness Programs
    - Bartow's Juneteenth event
    - Winter Haven's Fitness by the Fountain
  - Chairman for Bartow's fitness program - Fortress Fitness, which was recognized as a Healthy Weight Community Champion 2017 by the Florida Department of Health, State Surgeon General, Community Champion Recognition Program
  - Volunteers with Bartow Chamber of Commerce and Bartow Area Chamber Foundation Quality of Life Programs
- Kate Beamon
  - Volunteers each summer at Wekiva Youth Camp in Apopka, Florida with the 7th Grade Primitive Tent Camping Program

- Volunteers as a Leader for a Girl Scouts of West Central Florida (GSWCF) with a focus on STEM and outdoor activities
- Serves as volunteer GSWCF Service Unit Manager (South Lakeland/Mulberry)
- Recruiter, Event Coordinator, Public Relations Contact and Assistant Product Sales Coordinator for the Mulberry Highlands Service Unit of GSWCF
- Consults GSWCF staff on STEM activities and events
- Elected as an Area Delegate for voting at GSWCF governance meetings
- Selected and funded as one of five National Delegates to represent all GSWCF volunteers for governance voting at the National Council Session at the Girl Scouts USA national convention, G.I.R.L. 2017, in Columbus, Ohio in October 2017. This national convention of Girl Scouts only occurs once every three years.

Awards and Achievements

The Institute's staff members continue to serve on prestigious panels and committees, and their counsel is in constant demand internationally.

Dr. Brian Birky is Co-Convener of the PG NORM Working Group (Expert Panel) of the International Fertilizer Association (IFA). 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.

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). She is also a judge for the Florida Junior Academy of Sciences and the Army Education Outreach Program's National eCybermission Challenge. She is a member of the Polk Regional Science Fair's SRC (Scientific Review Committee), is an aquatics expert for Tampa Bay Regional Envirothon, and is involved with LE/AD (Lakes Education Action Drive) to educate the public about phosphate in the environment. She also works with Texas Instruments on STEM Education, beta testing new equipment and integrating science and engineering.

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 the internet to share information about its activities and promotes the websites www.fipr.state.fl.us and www.floridapolytechnic.org.

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.

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.

The FIPR Institute's K-12 STEM Education Program has substantially merged with Florida Polytechnic University's Education Outreach Team. Activities for the fiscal year are summarized below.

- STEM Activities with the YMCA
- Robotics partnership with FedEx
- After school STEM Program partnership with the City of Winter Haven Cultural Center
- After school STEM Program partnership with Parker Street Ministries in Lakeland, FL
- In-classroom STEM lessons - Polk, Hillsborough, Pasco, Sumter, Highlands, Duval, Clay, Lake, Indian River and Hardee Counties
- Water, Wings and Wild Things at Circle B Bar Reserve
- Collaboration with industry partner, Mosaic, in designing and presenting an activity at Agrifest
- MERIT Program

- Host on campus STEM activities at the University's iconic Innovation, Science and Technology Building (IST)
- Independence Academy
- RISK Group
- Heartland Group
- Earth Day - Sustainability
    - Florida Polytechnic Earth Day sponsored by SGA
    - Earth Day at Bok Tower Gardens
- Science and Engineering Fairs
    - Project Mentor
    - Assorted Local School Fairs in Polk, Lake, and Indian River Counties
    - Polk Regional Science and Engineering Fair
    - Heartland Regional Fair (Hardee, Okeechobee, Hendry, Glades, Highlands, Lee Counties)
    - Florida State Science and Engineering Fair
    - INTEL ISEF[1]
- Participated in the Great American Teach-In at several schools in Polk and Hillsborough Counties
- Florida Polytechnic Collaboration
    - Working with Admissions to inform them of upcoming activities; they are incorporating our team into some of the campus tours
    - Collaborating with the Presidential Ambassadors by providing them with educational outreach opportunities
    - Recruiting Florida Polytechnic student volunteers at Club Row
- Staff Continuing Education
  Florida Association of Science Teachers (FAST) Conference

[1]The INTEL ISEF is the largest event of its kind. There are other international science fairs, but none as large as the INTEL-sponsored one. Approximately 60 countries have students and judges participating each year. The event is an excellent way to stay informed about STEM education around the world, and can be a venue for recruiting top international students to Florida Polytechnic University.

Technical Exchange

FIPR Institute staff shared technical information and expertise at conferences and workshops both locally and abroad. We frequently serve as organizers, session chairs, and presenters. In addition, we publish both in-house and external papers as a result of our research and information programs.

This fiscal year, there were some notable events involving environmental and public health concerns that prompted the press and community groups to seek scientific opinions and comments from FIPR, which were seen in newspaper articles and television segments. Examples of the Institute's technology transfer activities are summarized below.

Presentations and Publications

FIPR Publication No. 02-191-256. Pilot Plant Demonstration of Sand-Clay-Overburden Mix for Accelerated Reclamation. MetPro Supply, Inc. in collaboration with University of Florida and Phosphate Beneficiation, LLC.

Birky, B. Town Hall Meeting, Lakeland. Presentation to the Grasslands and Oakbridge Communities. Radiation and mined lands. June 6, 2017.

Birky, B. Recent NORM Events in Florida. Presentation to the Florida Radiation Advisory Committee, Tampa. May 23, 2017.

Birky, B. Breaking News: Radiation Everywhere. Presentation to the Manatee County Citizens Advisory Panel. April 27, 2017.

Birky, B. "Phosphate 101" Presentation to Leadership Polk. January 26, 2017.

Birky, B. New Options for (Old) Residuals: Setting the Stage. IFA Global Safety Summit, Amman, Jordan. March 29, 2017.

Birky, B. Session III Chair. IFA Global Safety Summit, Amman, Jordan. March 29, 2017.

Hilton, J., Birky, B., Andresen, V., and Moussaid, M. Updates…New Delhi 2016, IFA PG Report, Policy and Regulatory Trends. IFA Global Safety Summit, Amman, Jordan. March 27-30, 2017.

Birky, B. NORM and Risk. IFA Global Safety Summit, Amman, Jordan. March 27, 2017.

Birky, B. and Hilton, J. Co-convenors. NORM / PG Working Group Meeting. March 27, 2017.

Chih-Hsiang Chien, Alex Theodore, Chang-Yu Wu, Yu-Mei Hsu, and Brian Birky. "Development of a Thoracic Personal Sampler System for Co-Sampling of Sulfuric Acid Mist and Sulfur Dioxide Gas." 2016 American Association for Aerosol Research (AAAR) Conference. Portland, OR. October 17-21, 2016.

Chih-Hsiang Chien, Alexandros Theodore, Chufan Zhou, Chang-Yu Wu, Yu-Mei Hsu & Brian Birky (2017): Development of a Thoracic Personal Sampler System for Co-Sampling of Sulfuric Acid Mist and Sulfur Dioxide Gas, Journal of Occupational and Environmental Hygiene, DOI: 10.1080/15459624.2017.1303575

Chih-Hsiang Chien, Alexandros Theodore, Chang-Yu Wu, Yu-Mei Hsu, Brian Birky. Upon correlating diameters measured by optical particle counters and aerodynamic particle sizers. Journal of Aerosol Science, Volume 101, November 2016, Pages 77-85. https://doi.org/10.1016/j.jaerosci.2016.05.011

Patrick Zhang, et al., editors, July 2016 Beneficiation of Phosphates: Comprehensive Extraction, Technology Innovations, Advanced Reagents.

Zhang, P., et al., "Rare Earths Recovery and Gypsum Upgrade from Florida Phosphogypsum," invited paper by the Minerals & Metallurgical Processing journal for 2017 publication.

Zhang, P., et al., "The Ultimate Mineral Processing Challenge: Recovery of Rare Earths, Phosphorus and Uranium from Florida Phosphatic Clay," invited paper by the Minerals & Metallurgical Processing journal for 2017 publication.

Zhang, P., et al., 2017, "Rare-earth leaching from Florida phosphate rock in wet-process phosphoric acid production," Minerals & Metallurgical Processing journal, Vol. 34, No. 3, pp. 1-8.

Zhang, P. Organized the CMI 2017 Workshop on Rare Earths and Uranium in Phosphate, Bartow, Florida, January 18, 2017.

Zhang, P. Serving as conference chair, started preparation for Beneficiation of Phosphate VIII to be conducted in Cape Town, South Africa, May 2018.

Zhang, P. Involved in organization, as the Technical Chair, of the 1st International Conference on Sustainable Development of Phosphate Resources, June 16-19, 2017, Yichang, China.

Zhang, P. Wrote the Phosphate chapter for the updated SME Mineral Processing and Extractive Metallurgy Handbook.

Zhang, P. “Rare Earths Occurrence in Florida Phosphate Ore and their Fate during Mining and Processing,” presented at Rare Earths 2016, June 5-10, 2016, Sapporo, Hokkaido, Japan.

Zhang, P. “Beneficiation and Leaching of Phosphate Process Streams for REE Recovery,” presented at The 8th International Conference on Rare Earth Development and Application, Aug. 2-6, 2016, Lanzhou, China.

Zhang, P. “Beneficiation and Leaching Techniques for Uranium Recovery from Phosphate Processing Streams,” presented at the IAEA Technical Meeting of the Uranium Mining and Remediation Exchange Group, September 26-29, 2018, Grand Junction, CO.

Zhang, P. “Reclaiming Phosphorus, Critical Elements and Uranium from Florida Phosphate Mineral Processing Tailings”, presented at Phosphates 2017, March 13-15, 2017, Tampa, FL.

Richardson, S.G. Natalgrass Control. Central Florida Invasive Species Management Workshop. April 19, 2017.

Albarelli, G, Lloyd, M. and Wojak, B. Sulphur Assisted Carbon Capture and Utilisation. Sulphur. July-August 2016.

Sukhraj, I. Implementing Generation-STEM* Classrooms, Presented at the Texas Instruments Leadership Summit, Tampa, FL, May 2017.

Press

Birky, B. Quoted in “Phosphate Scientist: Radiation is Zero”. Suzie Schottelkotte, Lakeland Ledger. June 7, 2017.

Birky, B. Wingate East Expansion and New Wales Sinkhole. Interview with Tony Pugh: Bradenton Herald via Washington, D.C. November 2016.

Birky, B. The JDC Kiln Process. Interview with Stephanie Claytor of Bay News 9. November 9, 2016.

Birky, B. Phosphate Operations in Florida. Interview with ABC Action News Tampa. November 3, 2016.

Birky, B. EPA Phosphate Industry Investigation in 2011. Richard Pollock, Senior Investigative Reporter, The Daily Caller News Foundation in Washington, DC. October 28, 2016.

Birky, B. Overview of the Phosphate Industry Worldwide. Farook Singh, Independent Producer affiliated with BBC, National Geographic and PBS. August 11, 2016.

Birky, B. Elevated Radioactivity in Some of the Wells Tested Near New Wales. Ryan Raiche with ABC Action News Tampa, WTFS. October 25, 2016.

Birky, B. Interpretation of Well Water Analyses. Aired TV with Shannon Behnken of "Better Call Behnken" on Channel 8. October 18, 2016.

Birky, B. "Mosaic to start sealing New Wales sinkhole by December" by Kevin Bouffard, Lakeland Ledger. October 18, 2016.

Birky, B. Personal Profile as an Industry Expert. Interview with Michael Lawton from Germany. October 13, 2016.

Birky, B. Natural Radioactivity in Water. On camera interview with Rick Elmhorst, anchor/reporter with Bay News 9, Tampa. October 12, 2016.

Birky, B. Story on JDC Phosphate's Technology in Sunday's Business Section. Kevin Bouffard, Lakeland Ledger. October 9, 2016.

Birky, B. Mosaic Phosphogypsum Stack Sinkhole and Water. Jesse Newman, Wall Street Journal, September 28, 2016.

Birky, B. Mosaic sinkhole. Kevin Bouffard, Lakeland Ledger. September 16, 2016.

Birky, B. "Digging in: Phosphate producer Mosaic is in it for the long haul" by Jerome Stockfisch, Tampa Bay Times. September 2, 2016 publication based on August 23 interview.

Birky, B. On New Manager, Walter Precourt, of Mosaic and the Future of Mining and Processing in Florida. Kevin Bouffard, Lakeland Ledger. August 24, 2016.

Richardson, S. USF Radio, Florida Matters: The Phosphate Industry. This was a panel discussion on the impact of the phosphate industry on Florida. Taped April 7, 2017; broadcast April 11.

Course and Conference Collaboration with Florida Polytechnic University

Participated in Florida Energy Systems Consortium (FESC) grant for Renewable Energy and Sustainability Course, Florida Polytechnic University, Fall 2016.

Sponsored Florida Academy of Sciences 81st Annual Conference at Florida Polytechnic University, March 10, 2017.

Research

FIPR Institute research projects are either conducted in-house or by various universities and private companies using Institute funds. FIPR Institute Research Directors serve as Contract Managers for all projects. Projects that were completed or ongoing during the fiscal year are described in the following text.

The Institute's Strategic Plan, available on our web site, covers the period 2011 through 2016, but has been indefinitely extended in an effort to coordinate with the University's Strategic Plan, which is still in development. The FIPR Institute's Strategic Plan discusses goals and approaches to achieve them in each of the Institute's research and programmatic areas. Unsolicited proposals that address these goals are encouraged.

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 described by title, funded organization, and a brief description of the objectives and accomplishments.

Recovery of Rare Earths and Uranium from Phosphate

FIPR Institute and the Critical Materials Institute

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). The FIPR Institute is undertaking the project on recovery of U and REE from phosphate mining and processing products as well as byproducts. All CMI members are shown in the figure below.

CMI member universities, national laboratories, and industry partners.

The FIPR Institute has hosted four annual workshops that reviewed progress of all member teams researching the recovery of REE and uranium from phosphate rock. There were 10 phosphate process streams characterized so that now the REE content, distribution and available forms are known. Beneficiation technologies to concentrate the REE have been developed for each of the six phosphate process streams. The FIPR Institute collaborates with other CMI member institutions and affiliates. ORNL research involving University of Tennessee students, and ThorOre in collaboration with University of Central Florida students, were hosted at the FIPR Institute laboratory facilities.

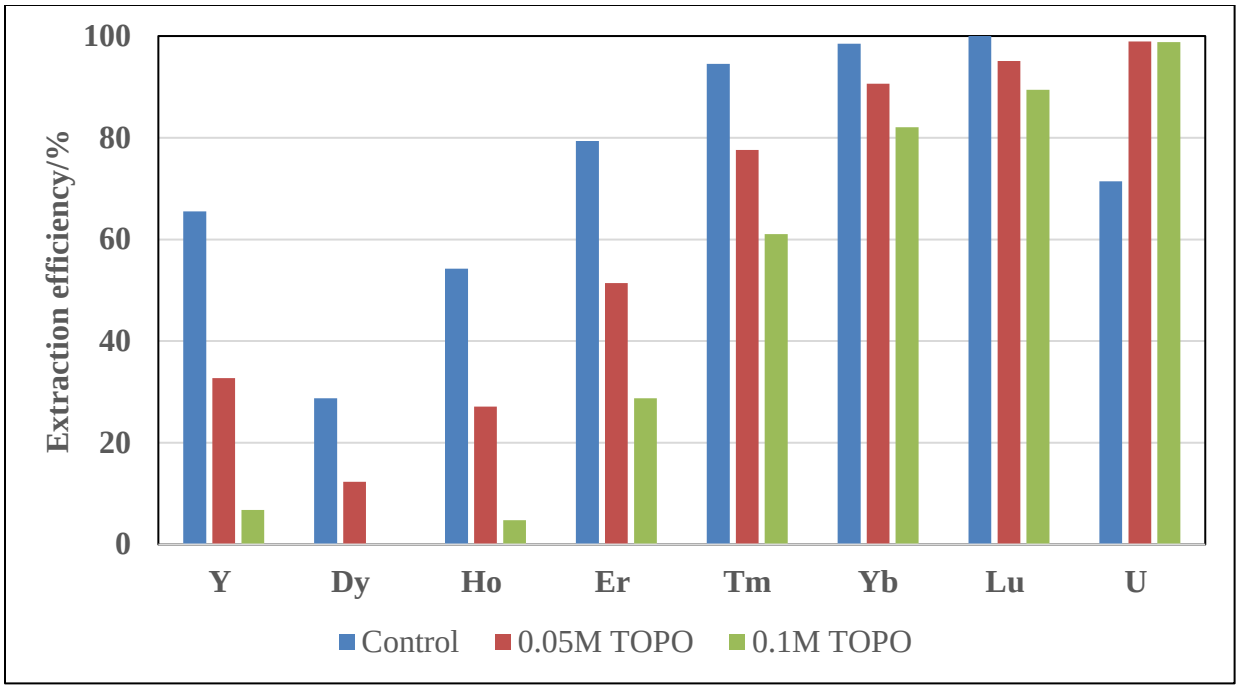
The major FIPR achievements under the CMI project are summarized as follows:

- gained a 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;
- 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;
- developed a multi-stage leaching scheme for recovering REE from PG using dilute sulfuric acid without infringing on the regulatory conditions of PG; and
- discovered a significant REE source material: sludge from phosphoric acid concentration/clarification.

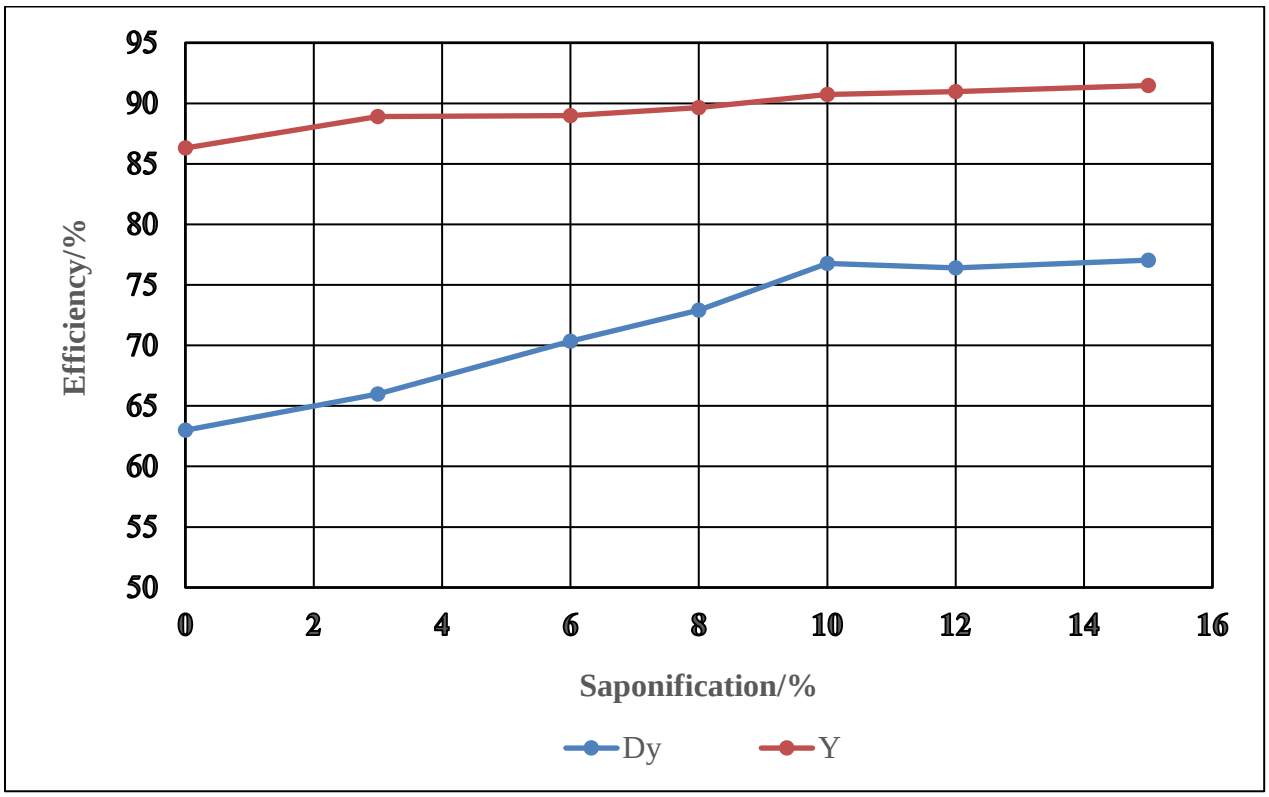
Recent achievements include:

- an extraction process was developed for simultaneous recovery of heavy rare earths and uranium from phosphoric acid;
- a processing scheme was designed for producing high-value phosphoric acid and heavy rare earths-containing solids from phosphoric acid sludge;
- a laboratory, continuous testing system consisting of gravity separation and flotation was designed for long-term investigation on recovery of rare earths, phosphorus and uranium from phosphatic clay; and
- four (4) peer reviewed journal papers were prepared and accepted for publication.

Participants of a Focused 2017 CMI Workshop on Down-Selecting Processing Flowsheets for REE Recovery from Phosphate Processing Streams.



Extraction Efficiencies of REEs and U from WPA with Mixture of 1.0M D2EHPA and TOPO.



Effect of Saponification of D2EHPA on Dy and Y Recovery from WPA Solution.

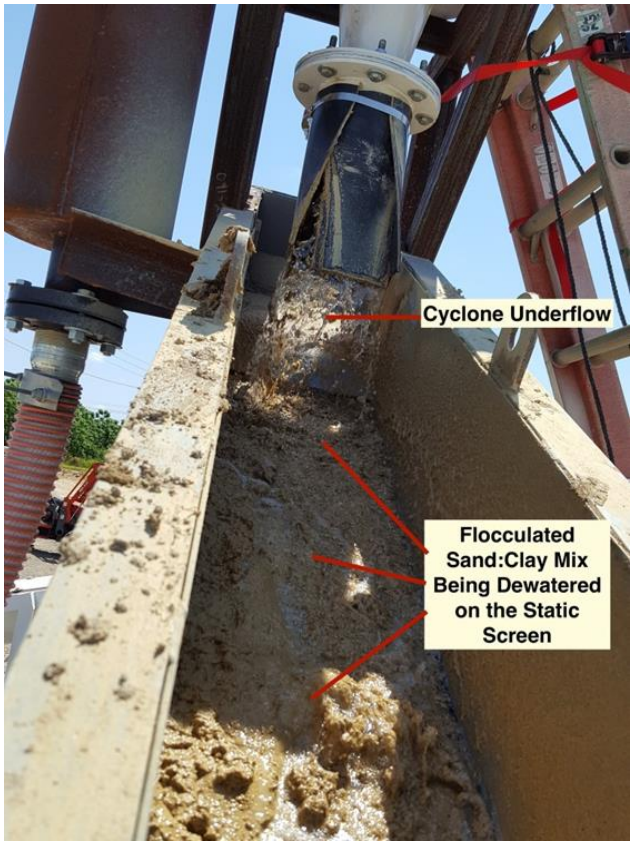
Pilot Plant Demonstration of Sand-Clay-Overburden Mix for Accelerated Reclamation

MetPro Supply, Inc.

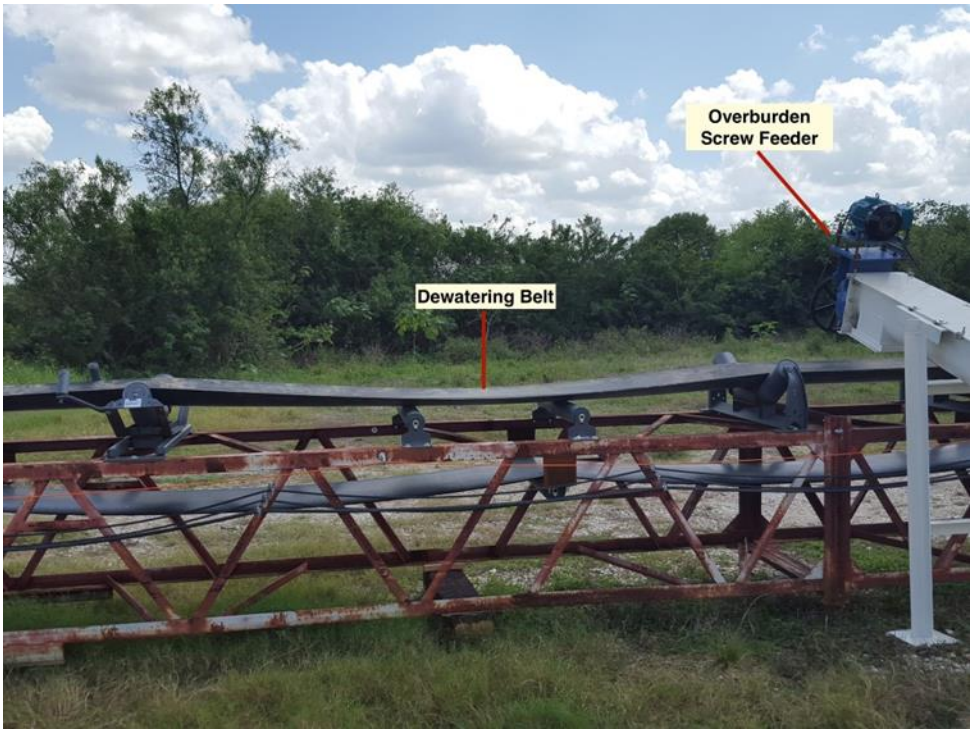
This project investigates the incorporation of overburden with the sand-clay mix; adding a new component (the overburden) to a previously tested method of accelerated reclamation. The following steps achieve almost instantaneous reclamation:

1. use a flocculation/thickening process for waste clay to achieve 15-20% solids;
2. mix the flocculated clay with sand to obtain a product containing 20-35% solids;
3. add additional sand to get percent solids in the mixture to as much as 50%; and
4. mix overburden with sand-clay to achieve >60% solids for reclamation of mine cuts.

The project was successfully completed and results exceeded expectations (FIPR Publication No. 02-191-256). The long-term, pilot scale demonstration showed that the mixture of tailings sand and clay could be dewatered to 50% solids or more in minutes. The solids content of the mixture of overburden, sand, and clay discharged from the pilot plant averaged 67% solids. Further dewatering of the pilot plant product to 80% solids was achieved by placing the mixture in an unlined trench for 10 days. From the technological point of view, it is a phenomenal accomplishment to produce flocs of sand-clay mix that can keep their integrity after going through hydrocyclone, screen and screw classifier.



Cyclone Underflow Discharge.



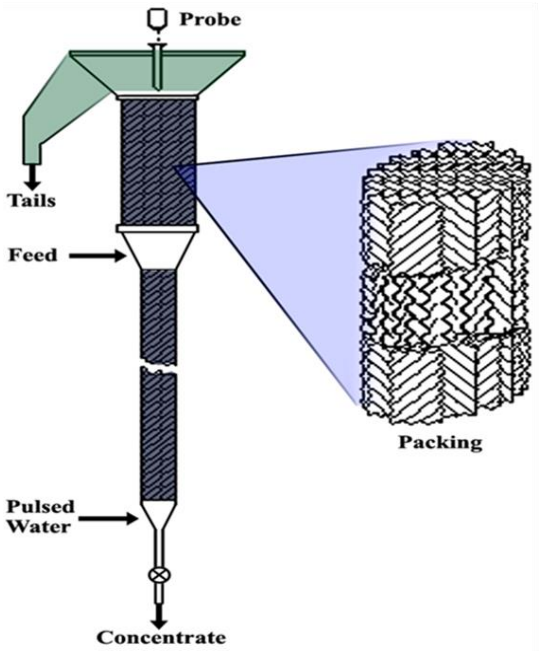
Overburden Screw Feeder and Dewatering Belt.

Removal of Dolomite from Florida Phosphate Pebble Using Packed Column Jig

Mineral Technologies International

The project was approved during the fiscal year and is in contract negotiations. It is designed to conduct continuous, pilot-scale testing of gravity separation using a packed column jig (PCJ) for separating dolomite from phosphate, thus allowing the use of large amounts of high-dolomite phosphate pebbles currently stockpiled or left in the ground. Dolomite, a natural contaminant in Florida phosphate rock, is a huge problem for fertilizer processing. The lower zone Hawthorne Formation being currently mined commonly has high MgO contamination. There are existing techniques for dolomite removal from phosphate rock, including: flotation, chemical treatment, and high-temperature treatment. All of these methods have some associated environmental issues.

The working principle of PCJ is demonstrated in the figure below. PCJ is a column filled with packing plates which are corrugated diagonally and set in an alternating configuration. The packing plates create a myriad of small cells in the column. A stream of mixed particles is fed through an inlet located near the top of the column. The feed point depends on the feed characteristics and concentrate grade target. A steady state water flow enters the bottom of the column and a pulsating flow is also superimposed to create a jigging action that maintains all particles in suspension limiting stagnation problems. The unique features of PCJ can be summarized as follows: 1) low energy use, 2) long, nearly unlimited separation zone, 3) small footprint, 4) minimal water use, 5) no chemicals used, 6) high throughput, and 7) effective for both coarse and fine particles.



Components of the Packed Column Jig.

Novel Technologies to Convert Dolomite Phosphate Rock into High Efficiency Slow Release Fertilizers

University of Florida

High dolomite phosphate rock is a worldwide problem in phosphate processing, and it is becoming more and more critical to the Florida phosphate industry. The wet process for phosphoric acid manufacturing is still the predominant technology for phosphate fertilizer production. This process generally requires a phosphate rock feed containing less than 1% MgO.

As the phosphate mining in central Florida moves farther south into the lower zone, the grade of the ore (matrix) gradually decreases, with dolomite being the major undesirable component. The flotation feed from the lower zone can generally be processed using the Crago double flotation process, but the pebble fraction averages 6% MgO and is currently stockpiled. The industry is estimated to generate close to one million tons of such high-dolomite pebbles per year. Other high dolomite phosphatic materials include waste clay and the oversize rejects from the washer. Finding beneficial uses for these dolomitic phosphate materials not only improves phosphate resource utilization efficiency dramatically, but also greatly reduces the environmental impacts of phosphate mining.

Recently, progress has been made in converting low grade phosphate rock into high efficiency, slow release P fertilizers by subjecting fine phosphate rock (PR) powder to reactions with some types of organic compounds called phosphate-activating agents. As a result, the surface of PR particles is covered with organic molecules, which markedly increase surface exposure to soil matrix and enhance physical, chemical, and biological reactions on the surface of PR. This two-year project includes 6 major tasks: 1) screening of activation agents to find the most effective; 2) optimization of the activation parameters; 3) physical and chemical characterization of the activated phosphate fertilizer; 4) greenhouse experiments to compare the new fertilizer with traditional phosphate fertilizers; 5) column leaching study to assess the environmental impact of the slow release fertilizer; and 6) economic analysis.

In the recently submitted project annual report, the research team presented the following encouraging findings:

- activation with selected organic molecules significantly increased water soluble P (WSP) in the dolomite phosphate rocks (DPRs), from ~5-15 to ~100-6000 mg/kg, varying largely among the different activating agents or their combination, and between the DPR samples;
    - organic molecules were coded as HA, LSS, and CA;

    - based on WSP, the activating efficiency decreased in the order of HA > LSS > HA+CA > LSS+CA > LS >CA,
    - both HA and LSS are effective in activating DPR, enhancing P release from DPR by 300-700 times, but HA is overall superior to LSS;
- based on sequential extractions, supply of P from HA- or LSS-activated DPRs is of slow release characteristics with 30-60% released in the first extraction, as compared to >85% from soluble phosphate;
- quantitative XRD analysis indicated that the activation process significantly increased the ratio of apatite/dolomite, which could be attributed to partial dissolution of dolomite by the organic agents, and thus promoted release of P from DPRs;
- the results from the optimization study based on one rock sample indicate that the optimized activation conditions are:
    - particle size < 100 mesh, 8% dosage of activating agent, reaction for 20 min, and at 20% moisture;
    - under optimized conditions, activation with humic acid can raise water soluble P from 9.4 mg/kg to 8790 mg/kg, as estimated by one-time extraction; and
- activation processes enhanced release of Ca and Mg from DPR, but had minimal influence on water solubility of trace metals including Fe, Mn, Cu, Zn, Cr, Cd, Pb and Ni.

Development and Demonstration of X-Ray Tomography for Plant-Site Characterization of Pebble Phosphate

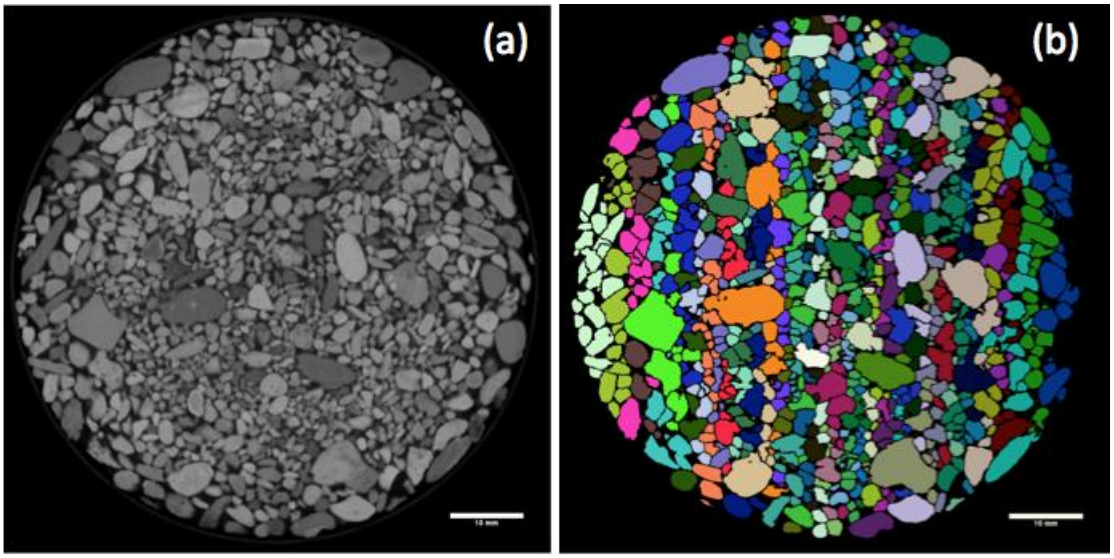
University of Utah

The central Florida phosphate industry has moved into the lower grade ore bodies from the Southern Extension, the lower zone of which is highly contaminated by dolomite, with the dolomitic pebbles being the major problem. Dolomite, or MgO, content is a major quality control indicator for the phosphate pebble product. Except for limited use of a laser based analyzer, current practices require either stockpiling of pebble product until quality control data from sampling become available, or making the shipping or discarding decision based on visual observations of rock as it is being produced. Therefore, instantaneous determination of MgO is of practical importance for better quality control. When flotation of dolomitic phosphate becomes necessary for removing the dolomite, on-line analysis of dolomite will become even more critical. This project is designed to develop a rapid analytical instrument method for quantifying phosphate rock composition on a moving belt, in a storage bin, or in a flotation cell, with the primary objective of determining dolomite (MgO) content. The method is based on X-ray tomography.

Samples of high and low MgO pebble phosphate from Mosaic's Four Corners operation and high MgO pebble phosphate from their South Pasture operation were collected, prepared, and shipped for high-speed X-ray computed tomography (HSXCT) analysis. Appropriate operating conditions for the HSXCT scanning of pebble phosphate have been established. Samples have been scanned and procedures for analysis established. Pebble phosphate samples of various amounts have been scanned in containers of different size to determine the maximum amount of sample that can be examined and still capture a high quality 3D image with and without beam hardening corrections. Finally, replicate (duplicate) samples were scanned in order to establish reproducibility and the statistical significance associated with sampling and scanning.

Scanning of pebble phosphate products has been demonstrated to be possible at a sampling rate of 0.4 - 0.6 kg/min using HSXCT with the automated VoluMax system available from ZEISS at an approximate cost of $850,000. The HSXCT data provides mineralogical and liberation analyses of dolomite and francolite with good reproducibility and good correspondence to chemical analysis. Although beyond the scope of this research project, the HSXCT data will allow the determination of the size and shape of the pebble phosphate particles. For about 1 kg of sample, the analysis time for mineral content is expected to be about 5 minutes and for mineral liberation about 15 minutes. These times can be reduced significantly if a high performance computer system is used.

ZEISS VoluMax 800 CT Machine for High-speed X-Ray Tomography.



CT Images: (a) 2D HSXCT and (b) Watershed Segmented Images of a High Dolomite Phosphate Pebble (No Beam Hardening Correction).

Leaching Study for Select Process and Non-Process Waters Relative to Future Disposal through a Deep Injection Well

Ardaman & Associates, Inc.

The current practice of pond water treatment and subsequent surface discharge is not only expensive, but also consumes a tremendous amount of fresh water. In the current pond water treatment and surface discharge practice, at least 5000 gallons of fresh water are used as dilution water for every 1000 gallons of process water treated to meet the requirement for conductivity. A typical PG stack system closure could require the treatment of over 3 billion gallons of process water, consuming 15 billion gallons of fresh water.

The Ardaman & Associates project is designed to study the feasibility of deep well injection of treated/partially treated water as an alternative to surface water discharge for phosphogypsum stack closure. The scope of work involves the following major components:

- characterizing 8 water sources for 21 water quality parameters;
- conducting various treatment tests on the waters;
- modeling the behavior of treated or partially treated water in various carbonate cores;
- performing leaching tests to determine carbonate core integrity with time in various waters; and
- analyzing all test data to provide guidelines for implementing the deep well injection method.

Treatment of Chemical Processing Pond Water and Precipitation of Phosphorus Using Nclear

Nclear, Inc.

Currently, the primary strategy for treating process wastewater is double liming, which requires raising the wastewater to pH 11 in two steps, stripping the water of undissociated NH_3, and reducing the pH back to ~ 6.5 by adding acid.
Nclear is a synthetic calcium (Ca) silicate mineral that induces and enhances phosphorus removal from water and wastewater. It requires lower pH for P removal than that required for double liming. Large scale tests showed that Nclear was more effective than alum or ferric salts for P removal.

The primary objective of the proposed work is to evaluate the efficacy and cost for phosphorus (P) removal from chemical processing pond water. Another advantage of using Nclear is better compaction ability of the sludge product.

Another potential application of Nclear is for phosphorus removal from flotation process water in the future when dolomite flotation is commercialized in Florida. FIPR has in development a flotation process for processing the high-dolomite phosphate pebbles. In this process, sulfuric acid must be used to adjust the slurry pH to about 5. This acid is also necessary for depressing phosphate to improve selectivity. The mild dissolution of phosphate rock at pH 5 results in high phosphorus content in the flotation process water. Studies showed that phosphorus content in the flotation process water averages about 100 ppm. When it is the time to shut down the mine, the phosphorus-containing process water must be treated for discharge, which could be very expensive. Water treatment using Nclear could reduce that cost.

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 has been testing the performance of two species of a leaf-gall-forming psyllid insect (*Calophya latiforceps and C. terebinthifolii*) 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.

Two insects have been and are being screened as possible biological control agents. Insects have been imported to quarantine labs both in Florida and in Brazil, and researchers have been working to rear them and assess their control performance and host specificity for Brazilian peppertrees.

Progress of the research project includes:

- a petition has been submitted to the USDA Animal and Plant Health Inspection Service (APHIS) requesting field release of *Calophya latiforceps* as a biological control agent on Brazilian peppertree;
- the USDA Technical Advisory Group recommended approval for release;
- continued research on *Calophya terebinthifolii* and a new *Calophya* species;
- populations of *Calophya* species are being maintained at Fort Pierce for continued research and possible release.

Uncontrolled Brazilian Peppertree.

Potential Biological Control of Cogongrass with the Indonesian Gall Midge, Orseolia javanica

University of Florida

Cogongrass (*Imperata cylindrica*) is a non-native and highly invasive rhizomatous grass that has infested thousands of acres of mined and non-mined lands in Florida. A gall midge insect (*Orseolia javanica*) has been discovered in Indonesia that attacks Indonesian strains of cogongrass. It is believed that the Florida strains of cogongrass may be genetically similar to the Indonesian strains and thus may be susceptible to attack by the Indonesian gall midge. A preliminary project was funded to determine if the Indonesian gall midge would be able to complete its life cycle on Florida cogongrass and inflict damage to the grass. In the project, cogongrass rhizomes have been collected from northern and central Florida; permits have been obtained; and the rhizomes have been shipped to Indonesia for testing.

Cogongrass Infestation on Former Mined Land

Establishment and Management of Vegetation Cover on Phosphogypsum Stacks
FIPR Institute

The initial research was conducted 1989-2004. Current efforts include 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.

Grass Established on a Phosphogypsum Stack.

The FIPR Institute's reclamation department has conducted extensive research on this topic. Mosaic asked for FIPR's assistance in providing training on earlier findings and in conducting further tests on potentially more cost-effective methods for pH adjustment and grass establishment on closed phosphogypsum stack side slopes. The FIPR Institute has conducted a training workshop for industry consultants. Field tests are being performed

on experimental methods of establishment and management of grass cover on closed stacks, to include the use of bermudagrass sod or hydroseeding and mulch applications.

Preliminary findings and/or recommendations include:

- do it right the first time (it is expensive to rework grass establishment areas);
- allow time for rainfall on the stack and subsurface drains to reduce the salinity and acidity before planting (this reduces the amount of lime that must be applied for pH balancing);
- if sod is to be used directly on phosphogypsum, it must be at least 95% bermudagrass (a grass species tolerant to acid and salt);
- mowing of grassed areas (primarily for weed control) should be reduced in frequency and mowing height should be increased (grass cover can be damaged by tractor tires sliding, even slightly, downslope and by mowing itself, particularly when the mower hits a high spot in the gypsum).

On-going work includes comparison of the cost-effectiveness of seeding techniques versus sod application.

Prior to the current work it was thought that, in general, if you roughen the surface of the phosphogypsum (through ripping or plowing on the contour), runoff would be decreased and more water from rainfall would be allowed to infiltrate into the stack and lead to more leaching (in combination with subsurface drains). Results are thus far inconclusive, so it may not be necessary to roughen the surface. We have observed pH increases from less than two to about four without any surface roughening by just letting the stack sit long enough. Good leaching occurs within the first year of stack closure, so waiting one year is adequate to bring the pH to 4 or slightly above and reduce the amount of lime required for good grass cover establishment. Tillage, however, is required to loosen the phosphogypsum surface prior to planting.

There are some new techniques being tried in the recent research, including the use of better quality sod of tolerant grass, allowing natural leaching to raise pH and reduce lime application, and testing potentially more effective hydro-seeding and hydro-mulching methods. The tests are on-going.

Native Wildflower and Grass Establishment

FIPR Institute and Florida Wildflower Foundation

This ongoing research project is a cooperative effort of the FIPR Institute, the Florida Department of Environmental Protection (FDEP), and the Florida Fish and Wildlife Conservation Commission (FWC) in addition to the grant funds from the Florida

Wildflower Foundation. The project focuses on the establishment of native wildflowers and grasses on disturbed lands (including mined and non-mined lands) and the control of invasive, competitive weeds.

Most of the weed seeds occur in the uppermost layer of soil. Soil inversion, using a moldboard plow, is being tested as a way to bury the weed seeds and thus prevent or inhibit weed seed germination, compared to shallow tillage by disking. The moldboard plow treatment showed some success, but the soil inversion achieved was sometimes incomplete, especially when plowing through sod. Research staff members and cooperators are currently in search of a deeper plow that would create more complete soil inversion.

The application of pre-emergent herbicides immediately after planting of small container-grown plants was found to be effective for preventing broadleaf and grass weed seed germination, reducing weed competition, and promoting good plant establishment and growth. At two of the study sites on former mined lands, either not treated with pre-emergent herbicides or after the pre-emergent effect had worn-off, the weeds were predominantly broadleaved plants. Where grasses had been planted, application of a selective post-emergent (applied to the leaves) broadleaf herbicide, which did not injure the grasses, resulted in reduced weed competition and good grass establishment and growth. Unfortunately, we don't yet have a post-emergent herbicide that could control broadleaf weeds without also severely injuring the planted broadleaved flowers, although it is possible to apply some grass killers without injury to the broadleaved flowers. We are continuing to work on selective control of various weeds with minimal or no injury to desired plants. The work includes control of very difficult perennial weeds as well as weeds from seeds.

Establishment of Native Plants on Impacted Lands.

Florida Industrial and Phosphate Research Institute

1855 West Main Street

Bartow, FL 33830

(863) 534-7160

www.fipr.state.fl.us

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