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Remediation of Metal-Contaminated Soils

contents

EDITORS:
Susan Curry
scurry@ufl.edu

Dr. Vimala Nair
vdn@ufl.edu

Dr. Lena Ma
lqma@ufl.edu

http://soils.ifas.ufl.edu

From the Chair...

Soils serve as major sinks for metals such as copper, zinc, arsenic, lead, cadmium, chromium, mercury, and others. Some metals are needed in trace quantities as nutrients to support biota growth, while others if accumulated in soils may be toxic to many biotic communities. Industrial wastes and biosolids, when land applied, can be a source of metals in soils. Metals such as iron, aluminum, calcium, and magnesium may present at high concentrations and these metals regulate the bioavailability of phosphorus in soils. In agricultural lands copper-based fungicides are a major source of copper, which tend to accumulate in soils and sediments of the drainage basin. In recent years several innovative techniques have been developed to reduce the bioavailability of these metals in soils. For example, Lena Ma's program has conducted extensive studies on remediation of metal contaminated soils. This includes discovery of a fern plant, which hyper-accumulates arsenic. This discovery received national and international recognition. The department is committed to strengthen the trace metal biogeochemistry programs to address current and future needs of our clientele, while advancing the science in this area. In this newsletter we present a few examples of research conducted in our department on the fate and transport of trace metals in a range of ecosystems.

K R Reddy

Join us at…
The 11th Annual Soil and Water Science Research Forum

The 11th Annual Soil and Water Science Research Forum is scheduled for September 10, 2010, in Gainesville, Florida. The forum is designed to bring together representatives from state and federal agencies as well as private industry, faculty, graduate students, and prospective students interested in soil and water science. The forum will provide an opportunity for all those interested in soil and water science to interact with our students, faculty, and administrators on campus. This year theme for the forum is on "Soil, Water Contamination and Public Health" , which is one of the thrust areas of the department. This year, **Dr. Ian L. Pepper**, Professor and Director, Environmental Research Laboratory, Soil, Water, and Environmental Sciences Department, University of Arizona, is the featured keynote speaker at the forum. We look forward to your participation in the forum. If you are planning to attend, please register at http://soils.ifas.ufl.edu/forum/.

For additional information, contact James Jawitz at Jawitz@ufl.edu.

Dr. K. Ramesh Reddy, Chair, Soil and Water Science Department,106 Newell Hall, Box 110510, University of Florida, Gainesville, Florida 32611.
Telephone 352-392-1803, Fax 352-392-3399, Email: krr@ufl.edu

Remediation of Copper-Contaminated Soils

The accumulation of copper (Cu) in soils under citrus production system in south Florida has been accelerated due to repeated and increased application of Cu-fungicides for preventing and curing of citrus diseases such as canker. A study by Zhenli He, Jinghua Fan, Xiaoe Yang, and Lena Ma found that total Cu in soil was as high as 1200 mg kg^{-1} in the Indian River area, as compared with 5-20 mg kg^{-1} for most non-contaminated agricultural soils. Contamination of soil by Cu causes phytotoxicity to citrus trees and poses a threat to the environment including water quality. Amendment of water treatment plant residuals (WTRs, consisting of mainly $CaCO_3$ and CaO) at 5 g kg^{-1} effectively reduced water soluble and exchangeable Cu in the soil, while increasing Fe and Al oxides-bound and residual Cu fractions. Application of WTRs at eight metric tons per hectare was observed to decrease Cu loading in surface runoff water under field conditions. Chemical remediation of soils can alleviate Cu-contamination problem but cannot solve the problem permanently as the fixed Cu can become active again when calcium is leached and pH decreases with time. Studies are underway to remove excess Cu in soil using Cu-accumulating plants, *Elsholtzia splenden and Elsholtzia argyi*, which were identified by Dr. Yang in China. These plants can accumulate Cu up to several thousands ppm in the roots and several hundreds ppm in the shoots (10-20 ppm for regular plants), with annual biomass yield up to 15 metric tons dry matter yield per hectare. Our preliminary results indicate that these plants can grow well under Florida climatic conditions and therefore have a potential for phytoremediation of Cu-contaminated soil in south Florida. For additional information, contact Zhenli He at zhe@ufl.edu.

Application of calcium water plant residues (Ca-WTRs) for remediation of Cu-contaminated soil

Immobilization of Lead and Arsenic in Shooting Range Soils

Both lead (Pb) and arsenic (As) are trace metals of great environmental concern due to their toxicity to both humans and animals. Elevated Pb and As concentrations have been found in shooting ranges since they are constituents of lead shot and bullets currently in use. Thus, it is important to understand the environmental fates of Pb and As in shooting ranges and develop best management practices (BMPs) to minimize their adverse impacts on the environment. Best management practices have been developed for Florida shooting ranges; however some of the methods recommended in the BMP are not well tested. The overall objective of this research was to develop a cost-effective amendment based on P or lime, combined with iron or clay to immobilize both Pb and As in shooting range soils. Phosphate (reacts with Pb), lime (increases pH) and clay (binds Pb) effectively immobilize lead in soils and are recommended by the Florida Department of Environmental Protection for application to shooting range soils. However, their effectiveness has not been shown in shooting ranges. While addition of phosphorus and lime may potentially increase As mobility in soils both clay and iron oxide have high affinity for binding As in soils, hence may be used in shooting range soils together with either P or lime to immobilize both Pb and As. For additional information, contact Lena Ma at lqma@ufl.edu

A typical shooting range in Florida with targets and a berm

Trace Metals in Coal Ash

Environmental impact is always an issue in the land application of coal ash products. Of particular concern is the possibility that trace metals accumulate in treated soils and in the edible parts of crops, and leach into groundwater. In a 3-year study of coal ash as soil amendments in south Florida, Yucong Li in collaboration with Jianjun Chen and Quigren Wang, showed coal ash application improved soil fertility and crop yield and had insignificant impacts on the accumulation of trace metals in soil, plant, fruit, and on groundwater quality. Greenhouse studies showed that coal fly ash amended at 18 kg m^{-3} of potting media neutralized potting media pH and provided nutrients for ornamental plant growth. Monitoring heavy metal leaching from the coal ash amended potting media during a 6-month plant production period indicated that As, Se, Mo, Cr, Pb, and Hg were not detectable in the leachates, and the amounts of Cu, Mn, Ni, and Zn in weekly collected leachates were relatively low. However, with a heavy loading rate (equivalent to 50 Mg ha^{-1}) of coal ash applied to a gravelly loam soil, concentrations of As, Cd, Cr, Ni and Pb in leachates were greater as compared to other soil amendments, such as biosolids and composts. Coal ash (fly ash and bottom ash) is a solid waste regulated at the federal level under the Resource Conservation and Recovery Act of 1976 and Subtitle C or D may apply. Subtitle D is for nonhazardous wastes that are subject to individual state laws. Most states including Florida have exempted coal ash from hazardous waste regulation. Coal ash management in Florida is covered by FAC 62-701, which has no specific requirements for land application. Nevertheless, FDEP requires the permit for using coal ash by following FAC 62-701, 62-709, and 62-4.070, which makes it almost impossible for agricultural use of coal ash. For additional information, contact Yuncong Li at yunli@ufl.edu.

Welcome… Incoming Students Spring 2010

MS

Ellen Bourne (Zhenli He)
Jacob Butterworth (Peter Nkedi-Kizza)
Cheryl Dunne (Zhenli He)
Jane Hart (Edward Philips/Patrick Inglett)
Nicole Howard (Todd Osborne)
Drew McLean (Rex Ellis/Amy Shober)
Rebekah Meyerholt (Lena Ma)
George Opderbeck (Maria Silveira)
Michelle Ouellette (Yuncong Li/Patrick Wilson)
Tina Patterson (Andy Ogram)

MS

Rima Tufino-Rath (George Hochmuth)
Jeffery Van Treese (Yuncong Li)
David Weddle (Cheryl Mackowiak)

PhD

Daniel Irick (Yuncong Li/Patrick Inglett)
Neil Young (John Cisar)
Yingia Zhu (Lena Ma/Willie Harris)
Ignacio Rodriguez (Gurpal Toor)

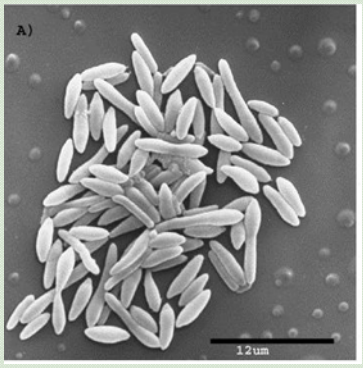
Arsenic-resistant Bacteria from the Rhizosphere of Chinese Brake Fern (*Pteris vittata*)

***Pteris vittata* growing in Florida**

Arsenic (As) hyperaccumulator *Pteris vittata* produces large amounts of root exudates, which are hypothesized to solubilize arsenic and maintain a unique rhizosphere microbial community. In collaboration with Max Teplitski, Anhui Huang identified 12 bacterial isolates tolerating 400 mM arsenate (AsV) in liquid culture, the most arsenic-resistant bacteria to date. Selected bacterial isolates were tested for their resistance to osmotic and oxidative stresses. Results showed a generally better growth under osmotic stress generated by arsenic than sodium chloride, demonstrating that arsenic detoxification metabolism also cross-protected bacterial isolates from arsenic-induced osmotic stress. After 32 h of growth, all arsenate was reduced to arsenite (AsIII), but arsenite remained unchanged. Sensitivity to hydrogen peroxide (H_2O_2) was similar to that in broad-host pathogen *Salmonella enterica* sv Typhimurium wild type. The results suggested that these arsenic-resistant bacteria are metabolically adapted to arsenic-induced osmotic or oxidative stresses in addition to the specific bacterial system to exclude cellular arsenic. Both these adaptations contribute to the high arsenic-resistance in the bacterial isolates. For additional information, contact Lena Ma at lqma@ufl.edu.

Metals Research in the Soil Microbial Ecology Laboratory

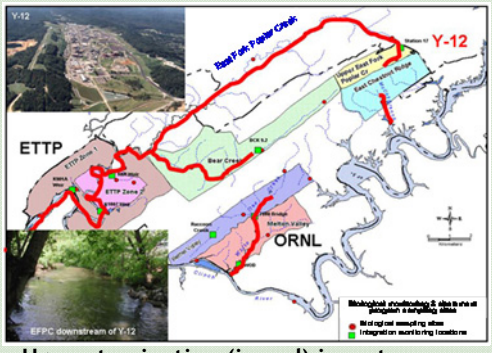
The first work on metal research by the Soil Microbial Ecology Lab was conducted by Kanika Sharma Inglett in 2002, who defined potential biological mechanisms involved in remediation of chromium (CrVI), an EPA priority pollutant. Inglett's research described the role of fermentative bacteria in the reduction of CrVI, which has implications in the broader context of bioremediation. She isolated several microbial consortia from a wetland soil heavily contaminated with Cr via enrichment with various electron donors and acceptors. Several CrVI-reducing strains were isolated from these consortia, and fermenters proved to be most efficient at CrVI reduction. One of these strains, a novel species belonging to the genus *Clostridium*, reduces CrVI to CrIII by use of electrons shuttles such as FeIII and the humic acid analogue AQDS. She conducted an array of studies on the kinetics of CrVI reduction by this strain in the presence of various electron shuttles, and investigated their impacts on potential shifts in fundamental physiology of the strain via production of fermentation products.



The novel metal reducing bacterium, *Clostridium* CFO-6

A new student in the department, Chris Weidow, is interested in mercury (Hg) transformations in the Everglades. Mercury deposition is greater in the Everglades than any other area in the Eastern US, and its subsequent transformation by soil bacteria to the more dangerous methylmercury is of great concern due to human health impacts. Inorganic mercury is generally thought to be methylated by sulfate reducing bacteria and iron reducing bacteria. The biogeochemical context of mercury methylation in the Everglades is quite complex, with a variety of factors controlling the bioavailability of mercury and the activities of methylating and demethylating bacteria. Chris will investigate the physiological ecologies of methylating and demethylating bacteria along environmental gradients in the Everglades. For additional information, contact Andy Ogram at aogram@ufl.edu

Colloid-Facilitated Mercury Transport and Methylation



Hg contamination (in red) in water, sediment and biota in the streams of Oak Ridge Reservation (http://www.esd.ornl.gov)

Due to its toxicity and potential to biomagnify in food chains, elevated mercury (Hg) in soils and aquatic systems is of great ecological concern at many Department of Energy (DOE) sites including Oak Ridge in Tennessee. Its accumulation and movement in the environment is complicated due to biogeochemical sensitivity and potential to strongly associate with soil components. The adsorption of Hg by soil components doesn't assure immobility in cases where components can be mobilized as colloidal particles. Hence, colloid-facilitated transport is a factor that must be accounted for in predicting the fate of Hg. Faculty of the Soil and Water Science Department (Willie Harris, Lena Ma and Yuncong Li) in collaboration with Dr. Bin Gao and J.C. Bonzongo from other departments have initiated interdisciplinary research focused on a more thorough and integrative understanding of Hg transport. The objectives are to investigate Hg mobilization mechanisms and develop predictive models that realistically account for soil complexities affecting Hg transport. This integrative approach will couple knowledge in colloid transport in heterogeneous porous media with biogeochemistry of Hg (e.g., methylation) to gain insight in Hg dynamics at Hg-contaminated sites. Results will be pertinent to effective remediation of Hg-contaminated soils and watersheds. For additional information, contact Willie Harris at apatite@ufl.edu.

Field-scale Phytoremediation of Arsenic-contaminated Groundwater using Chinese Brake Fern (*Pteris vittata*)

In collaboration with Dr. Robert Stamps, a field-scale hydroponic system to phytoremediate arsenic-contaminated groundwater using the first-known hyperaccumulator Chinese brake fern (*Pteris vittata*) was tested successfully for the first time. In this field study, two water sources were used to compensate for evapotranspiration loss [high-As water (140 and 180 μg L^{-1}) or low-As water (<7 μg L^{-1})] and three frond-harvesting regimes (15 cm above rhizome, selective harvest of mature fronds, and infrequent/no harvest) were investigated. The study was conducted for 34 weeks with two cycles of water change (Cycle-1 and Cycle-2) using the same plants. During Cycle-1, arsenic was reduced from 140 to <10 μg L^{-1} in 8 weeks in tanks refilled with low-As water compared to 17 weeks in tanks refilled with high-As water. Reusing the same ferns in Cycle-2 with higher initial As at 180 μg L^{-1} further reduced the remediation time by 2–5 weeks, indicating that more established ferns removed arsenic more efficiently. Selectively harvesting mature and senescing fronds coupled with refilling with low-As water was the most effective practice whereas harvesting all fronds while continuously exposing the ferns to high-As water was the least effective. For additional information, contact Lena Ma at lqma@ufl.edu.

Chinese brake ferns growing in arsenic-contaminated groundwater

Congratulations!

Fall 2009 Graduates

MS

Pamela Sue Brown (Alan Wright)
Robert Compitello (Todd Osborne)
Melinda Hooper (Chris Wilson)
Ronald Lindemann (Samira Daroub)
Shawna J Loper (Amy Shober)
Laura P Sadowski (Jerry Sartain)
Neil G. Young (George Snyder)

Spring 2010 Graduates

PhD

Sylvia Lang (Mark Clark & Samira Daroub)
J. Rowland (John Cisar)
Rongzhong Ye (Alan Wright & Ramesh Reddy)

MS

Kristin Campbell (Chris Wilson)
Marie-Jacqueline Depaz (Kelly Morgan)
Diane Racine (Maria Silveira)
Altamirano Vargas (Jerry Sartain)

BS

Zimrisha Alla
William Mahler
Mia Requesens

SWS Minor

Charles Cox
Erika Larsen
Chad Martin

Faculty, Staff, and Students

Congratulations to our faculty, staff, and students for their outstanding accomplishments in soil, water, and environmental sciences.

John Cisar, Affiliate faculty member, was elected Fellow, Crop Science Society of America in 2009, and was recognized in Pittsburgh, PA, at the Annual Meeting of ASA-CSSA-SSSA.

Sabine Grunwald was selected to receive the 2010 NACTA Teacher Fellow Award. This award is given by North American Colleges and Teachers of Agriculture (NACTA). She will receive this award at the 56th Annual NACTA/SERD Conference, which will be held at the Pennsylvania State University campus, State College, PA during June 22-25, 2010.

Edward Hanlon, Southwest Florida Research and Education Center, recently received the "CAST Champion Award." The Council for Agricultural Science and Technology (CAST) expresses its sincere gratitude and appreciation for Hanlon's exemplary service and outstanding contributions while serving for 11 years as a CAST Board Member, Adviser to the CAST Staff, and Treasurer of the Corporation. The CAST Champion Award honors those individuals who volunteer their "time, talents, and personal contacts to benefit CAST in extraordinary ways."

John Bonner (left) awarding the 2009 CAST Champion Award to Ed Hanlon (CAST archives)

The Council for Agricultural Science and Technology (CAST) prepared an issue paper and video on Water, People, and the Future: Water Availability for Agriculture in the United States. **James Jawitz**, is one of the coauthors of the paper and also featured on the video. See *http://www.cast-science.org/*

Sabine Grunwald and **Ramesh Reddy** were named as UF Research Foundation Professors for 2010-2013. The recognition goes to faculty members who have a distinguished current record of research and a strong research agenda that is likely to lead to continuing distinction in their fields. Since the inception of this award (in 1998), 13 Soil and Water Science faculty have received this recognition. Each year only one faculty member can be nominated from each unit.

Zhenli He received 2010 UF/IFAS Superior Accomplishment Award in the category of Academic Personnel.

Warmest congratulations to **Kelly Jacoby** for receiving the 2009 Superior Accomplishment Award of the SWSD.

Debolina Chakraborty (advisor, Vimala Nair) was placed third in SSSA divisions S-4 and S-8 at the Graduate Student paper Competition at the Annual Meetings in Pittsburg, PA in November 2009.

Ryan Graunke, an SNRE graduate student (advisor, Ann Wilkie) was awarded a Southern Region Sustainable Agriculture Research and Education (SARE) Graduate Student Grant for a project entitled "Bioenergy and Biofertilizer for Small-Farm Enterprises."

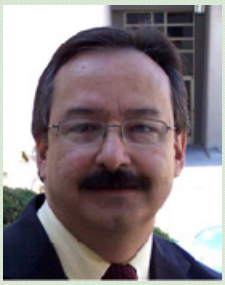
Augustine Obour (advisors, Maria Silveira and George O'Connor) won the second place at the graduate student competition – ASA Division A-5 – 2009 annual meeting in Pittsburg, PA (Nov. 1-5, 2009).

Julia Showalter (advisor, Vimala Nair) was awarded the first place at the student presentation contest at the recently concluded Southern Branch ASA meetings in Orlando, FL, February 7-8, 2010.

A student design team under the advisement of Ann Wilkie was awarded a Phase I EPA P3 (People, Prosperity and the Planet) grant to design an eco-energy model linking

Soil and Water Science Distinguished Seminars

Dr. Jorge Gardea-Torresdey, Dudley Professor of Chemistry & Environ. Science & Engineering, Chair of Department of Chemistry, The University of Texas at El Paso, TX presented a seminar entitled "Toxicity and biotransformation of metal oxide nanoparticles in terrestrial plants" on March 12, 2010. Dr. Gardea-Torresdey research interests include metal binding to biomaterials for remediation of contaminated waters, phytoremediation, bioproduction and fate of nanoparticles in the environment. Dr. Gardea-Torresdey is a co-investigator for the "Center for Environmental Implications of Nanotechnology" funded by NSF/EPA. His research achievements were recently highlighted in the Lawrence Hall of Science at the University of California Berkeley. He received the 2009 SACNAS Distinguished Scientist of the Year Award. He was highlighted by the journal *Nature* in the December 3, 2009 Issue. Dr. Gardea-Torresdey has also made significant contributions to the scientific community. He currently serves on the Editorial Board of 7 journals including Environmental Science and Technology and Environmental Toxicology and Chemistry. He was appointed as the Editor of the Journal of Hazardous Materials in 2007, which ranks number one in the civil/environmental engineering field. For additional information related to Dr. Gardea-Torresdey's research program, please visit **http://www.gardea.utep.edu.**



Dr. Johan Bouma , Emeritus Professor of Soil Science, Wageningen University, The Netherlands, presented "The role of soil science in sustainability studies" on April 15, 2010. Johan Bouma is a member of the Royal Dutch Academy of Sciences (RDAS) (1989), a Fellow of the Soil Science Society of America (1983) and an honorary member of the International Union of Soil Science (2006). He was a member of the Scientific Council for Government Policy in the Netherlands (a think-tank in the prime minister's office) from 1998-2003. Professor Bouma is now chair of the scientific advisory council of a national research program on sustainable agriculture. His research interests are in the field of Hydropedology and Land-use Policy, and covered water and solute movement in structured soils; relating soil morphology to flow patterns; development of pedotransfer functions; effects of soil management defined in terms of phenoforms to be derived from a given taxonomic soil-genoform; land use policy; and interactive research with stakeholders and policy makers. Seminar can be viewed at: **https://swsde.ifas.ufl.edu/**

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methanogenesis and photosynthesis to utilize wastes and generate biofuels. The team includes **Scott Edmundson** (SNRE), **Ryan Graunke** (SNRE) and **Jon Alldridge** (ABE).

A publication by **Mengsheng Gao, Melanie J. Barnett, Sharon R. Long, and Max Teplitski** made it to the cover page of the journal of Molecular Plant Microbial interactions and is available online at *http://apsjournals.apsnet.org/page/mpmi_cover_4-10*. Congratulations to the authors!

Fall 2009 - CALS Dean's List

Congratulations to **Jennifer Frey**, **Kimberly Johnson**, and **Kayla Milburn** for achieving this recognition. CALS Dean's List criteria are a 3.70 GPA with a minimum of 12 semester hours of graded credits.

Congratulations to the following students who were recipients of SWSD 2009 awards

William Mahler: Outstanding Undergraduate Award

Mia Requesens: Frederick B. Smith Scholarship

Luke Gommerman: Victor W. Carlisle Scholarship Award

Manmeet Waria: Sam Polston Scholarship Award

Shiny Mathews: Sam Polston Scholarship Award

Davie Kadyampakeni: William K. (Bill) Robertson Scholarship Award

Dr. Mary E. Collins Retires

Mary E. Collins grew up in The Bronx (NYC) and the Catskill Mountains (Wurtsboro, NY). Her mother was a bookkeeper. Her father was a lawyer, later in his career a NYS judge. Therefore, she did not come from an agricultural background. It was in high school taking an Earth Science class that she became interested in agriculture. Mary was not a very good student in high school so the opportunity for college was limited to two-year colleges. She ended-up attending the State University of New York (SUNY) at Cobleskill, a two-year agricultural and technical college in upstate NY. There she found her calling. During her first semester she took her first soil science course. The professor talked about the soil survey program and how one could be a soil scientist with the USDA. Mary applied and was accepted becoming the youngest (18 yrs old) soil scientist ever hired in NYS. She was also the second woman ever hired as a soil scientist in NY. During her college-years she worked for the USDA – Soil Conservation Service (SCS; now the Natural Resources Conservation Service).

At Cobleskill she learned how to milk and show a cow, shear sheep, drive a tractor, and overhaul a combine. She was a very good softball and basketball player earning three varsity letters. Most importantly, she became an exceptional student. Therefore, after receiving her AAS degree she continued her undergraduate education at Cornell University. At Cornell she was President of the Agronomy Club, represented the club at the ASA meeting, and was in the honors program. Her honors research was on soil survey interpretations for urban soils. She continued to work for SCS during this time. One of her professors at Cornell recommended that she go to Iowa State University for her MS. Her next stop was the Hawkeye State.

Mary asked SCS to transfer her to Iowa. She was stationed in Elkader, Iowa. This area of Iowa is known as "Little Switzerland" because of the beautiful hilly landscapes. There she met her husband-to-be and her "Iowan mother." Mary completed her MS degree at ISU studying physical and chemical properties of eroded biosequences. Her PhD involved statistically modeling the geographic extent of the Colo soils series (mixed, mesic, fine-silty Cumulic Haplaquoll). During her PhD program Mary was asked to return to Cornell as a faculty member to teach for one semester. That experience sealed her desire to join a university to instruct and mentor graduate students. After being the first woman to receive a PhD in soil science at Iowa State, her next stop was the Sunshine State.

Her research has been cutting-edge since she first arrived at UF in 1981. One of her first projects was to computerize the Florida soil survey information. She was very involved with the Florida Characterization Program and the National Cooperative Soil Survey Program being the Florida Agricultural Experiment Station representative from 1990 to 2001. Much of her early research was in support of the soil survey program. Mary Collins is internationally known for her research using ground-penetrating radar to investigate subsurface features. These radar investigations included her work with forensic anthropologists to locate buried bodies. She has been invited to more than 20 countries giving key note lectures, seminars, and teaching students. Recently, her research has been studying subaqueous soils in near- coast environments. She taught undergraduate, graduate, and short courses as well as coached the Soil Judging Team. She has especially enjoyed the travel courses she formed. Since 2001 Mary has been the Undergraduate Coordinator and very much enjoyed her time helping undergraduate students.

Dr. Collins has won several awards and honors. At UF she awarded a TIP award for her teaching and two PIP awards. She was elected Fellow in the American Society of Agronomy (ASA) and the Soil Science Society of America (SSSA). Mary served on the National Academy of Sciences – National Committee for Soil Science. Her greatest professional honor came when she was elected President of SSSA. In her leadership role she was instrumental in establishing the SSSA K-12 Education Committee, securing the necessary funding for the Smithsonian Soils Exhibit, and welcoming the World Congress of Soil Science to the United States. In 2007 she was honored as "Distinguished Alumna" at SUNY Cobleskill.

After 29 years in the department Dr. Collins retired March 19, 2010. She and her husband Ron are moving their two dogs, one cat, and two horses to Iowa to be closer to Ron's family and her Iowan mother. She will continue to be involved with the department by teaching distance education courses from afar.