

2021 Annual Meeting Report

Basic Information

Project No. and Title: NC1187: Particulate Reactivity and Cycling in a Changing Environment: Implications for Agriculture and Human Health

Period Covered: 10/01/2020 to 09/31/2021

Date of Report: 02/14/2022

Annual Meeting Dates: 12/13/2021 to 12/13/2021 (virtual)

Participants

Stephen Anderson - University of Missouri (MO); Jorge Guzman- University of Illinois (IL); Ganga Hettiarachchi- Kansas State University (KS); Jeffery Jacobsen- Michigan State University (MI); Alexandra Kravchenko - Michigan State University (MI); Martin Pantrak- Geological Survey (IL); Don Sparks - University of Delaware (DE); Daniel Strawn - University of Idaho (ID); Joseph Stuckey- University of Illinois (IL); Wei Zhang - Michigan State University (MI).

Brief Summary of Minutes of Annual Meeting

The participants gave introductions and shared their research activities in the past year. The participants discussed potential collaborations. The group discussed strategies to recruit new members to this group. One potential approach is to engage early career researchers (e.g., graduate students and postdocs) by encouraging and providing support for them to attend our annual meeting. The group discussed the nomination for multistate research award and decided to delay the nomination for one year to enhance collaborative group activities. State research reports (highlighting member collaborations) from each state to be sent to the group chair by mid/late January to compile the group report.

New ideas and suggestions for group activities: Don Sparks will take the initiative to organize a workshop focusing on frontiers in synchrotron-based techniques to study soils at the NSLS II, Brookhaven National Laboratory possibly in the Fall 2022. This effort was postponed in last year due to the COVID-19 pandemic. The annual meeting will take place in conjunction with the workshop. Alexandra Kravchenko plans to propose a joint session on the effect of cover crops on soil structure in the 2022 tri-societies annual international meetings. Wei Zhang will take the initiative to organize a series of webinars on spectroscopic and molecular methods (e.g., spectroscopy and mass spectrometry) for investigating soil systems in 2022 and 2023.

The 2022 Annual Meeting venue: The group agreed to have the Annual Meeting concurrently with the NSLS II workshop.

The group leadership: The group decided the term limit of the group leadership is two years. This will allow for leadership rotation and shared responsibility among group members. Current leadership: Chair - Wei Zhang (2022-2023); Vice-Chair – to be identified; Secretary – to be identified.

Accomplishments

Members of this multistate research project investigated the influence of cover crops on soil structure, processes and speciation of heavy metals in soils, speciation and transport of phosphorus (P) in soils, cycling of C from Fe-bearing soil minerals, the effect of salinity on C cycling, efficacy and mobility of Zn fertilizers, and recovery of portable water from wastewater sources, and emerging contaminants (e.g., silver nanoparticles, antibiotics, and prions) in soil, water, and plant systems, using a multitude of spectroscopic, molecular, and experimental methods. The results demonstrated added benefits of cover crops in improving soil pore structure for additional water storage and movement through soil profiles. Fundamental knowledge on P speciation and transport help better utilize P fertilizers while avoiding the excess loss of P to water bodies. Improved understanding on environmental processes of conventional and emerging contaminants is important to remediate soil pollution and ensure water quality and food safety. Development of technology in reclaiming water from wastewater sources is key to agricultural water sustainability. Finally, fundamental understanding on the effect of sea-level rise and soil salinity on C cycling is essential to addressing the impact of climate change.

In terms of collaborative activities, Daniel Strawn from University of Idaho and Ganga Hettiarachchi from Kansas State University collaborated on a review of trace elements in the environment. Wei Zhang co-authored a review paper on fate and transport in environmental quality with authors from multiple States. Several members of the multistate group organized a symposium at the 2021 annual meeting of the Soil Science Society of America with talks on rates and mechanisms of soil chemical processes important for solving society's grand challenges, including climate change, soil health, environmental risks, and food safety and security. Presentations included invited speakers and volunteered talks, and a special tribute to multistate member Dr. Donald Sparks.

More State-specific research activities are detailed below.

At University of Missouri Stephen Anderson's group differentiated geometrical pore characteristics between CC and no cover crop (NCC) by micro-Computed Tomography (μ CT). The study site was managed with a corn (*Zea mays* L.)-soybean (*Glycine max* (L.) Merr.) rotation and no-till management with and without winter CC at the University of Missouri Bradford Research Center. The total pore volume was significantly greater in CC compared to NCC with 8.4- and 2.5-times greater values in CC at 7.25 to 27.25 and 37.25 to 57.25 mm, respectively. The total (individual + branched) pore count and the individual pore count were significantly greater in CC compared to NCC for both depths. The porosity of CC soil at 7.25 to 27.25 mm depth was 10 times greater than that of NCC and the difference was not significant at 37.25 to 57.25 mm depth. The mean branch length, longest path length and mean tortuosity were not significantly different between the two treatments at any considered depth. The micrometer scale determination of geometrical pore network characteristics showed added benefits of CC use compared to NCC. These changes reflect improved soil structure and pore networks for additional water storage and movement through the profile.

At University of Idaho, Daniel Strawn's group focuses on understanding processes and species of chemicals in soils, together project participants, using the integration of advanced

spectroscopic and molecular techniques and the methods to integrate analysis of spatial resolution of soil with speciation analysis. Particularly, characterization of trace metals in the environment is a major issue for maintain environmental health.

At University of Delaware, Donald L. Sparks's group has focused their NC1187 research on: speciating P in high P soils, resulting from long-term amendments of inorganic, and especially organic sources, derived from poultry operations; and the impacts of salinity, due to flooding and sea level rise on cycling of nutrients and carbon. By determining the solid-phase P species (forms) in high P agriculture soils, we are in a position to better understand P mobility, and therefore, availability to plants and environmental susceptibility to P losses. Recent developments in synchrotron-based light sources are now allowing one to determine direct solid phase soil P speciation using a micro-sized beam with high precision and accuracy. New advances at the National Synchrotron Light Source at NSLS II enables one to couple P speciation and other lighter element speciation at the TES microprobe beamline with speciation of elements such as Fe other heavier elements at the XFM microprobe beamline. We were able to demonstrate the spatial distribution and co-location of P with Al, Si, S, Fe, Ca, Mn, and As using soil thin sections. The XFM beamline, after fluorescence mapping, was used to determine P speciation at the micron scale. Depending on soil pH, P was strongly associated with Al, Ca, and Fe in both sorbed and precipitated forms. In terms of the impact of salinity, due to sea level rise, on coastal soils, we studied the role that various salinity regimes had on the cycling of C from ferrihydrite, a major Fe-bearing mineral in soils. We found that with higher salinity and ionic strengths, that C was bound less to ferrihydrite suggesting that under saline conditions C could be lost and released to water and the atmosphere. These results are important as more agricultural soils along the Mid-Atlantic U.S. coast are becoming salinized, which has detrimental impacts of crop production.

At University of Illinois, Yuji Arai's group investigated colloidal P (CP) and P speciation in soils. Physicochemical properties of water-extractable colloids (WECs) from the soil profile at 0-180 cm were characterized using conventional wet chemical analysis. Solution P-31 nuclear magnetic resonance spectroscopy (NMR), P and Fe K-edge X-ray absorption spectroscopy, and transmission electron microscopy were also used to understand P speciation and mineralogy of CP. The importance of mobile CP is often associated with sediment loads in surface runoff, but the recent study clearly showed the presence of mobile CP below the surface. The mobility of P-rich WECs should not be neglected in predicting TP loss to subsurface flow. During storm events, the loss of dissolved- and colloidal-organic P from soil to water system can be substantial, especially for the manure-applied pasture. The transport of organic P and the change in the organic P /phosphate ratio from agricultural systems to water should be of concern as it may affect P cycle in soils and the fate of P in the soil-water environments.

At Kansas State University, Dr. Ganga Hettiarachchi's group and collaborators at Texas A&M (Aditi Pandey, Paul Schwab) collected and analyzed STXM-NEXAFS (spectromicroscopy) data from the Canadian Light Source (CLS), Saskatoon) remotely to identify amorphous phase materials in a Martian analog. The Hettiarachchi team and a team from K-State College of Engineering (Dr. Prathap Parameswaran team) have been working on testing the hypothesis that innovative wastewater treatment technologies can produce potable water from different sources

(municipal or livestock wastewaters such as swine wastewater), while recovering nutrients and C-rich soil amendments for crop production. The teams use Anaerobic membrane bioreactors (AnMBR) and Microbial Reverse Electrodialysis Cells, fairly new technologies, that can operate sequentially and remove harmful substances from wastewater to produce clean water for reuse. These processes also produce nutrient-rich co-products, allowing balanced/tailored nitrogen and phosphorus source recovery for agriculture. In 2021, the team focused more on optimizing the recovery of Ca-based P sources from simulated swine wastewater> For this work P-XANES data was collected at the APS Sector 9. Additionally, Hettiarachchi team investigated the efficiency of few different Zn sources using plant, soil incubation, and synchrotron-based studies (at the APS, Sector 5). Improved understanding of the fundamental mechanisms responsible for the enhanced mobility or availability of different Zn fertilizers in carefully selected soil types will help to determine under which circumstances different Zn fertilizers offer the potential to increase agricultural productivity significantly.

At Michigan State University Dr. Wei Zhang's group focused on the fate and transport of emerging contaminants in soil, water, and plant systems. Specifically, his group studied the internalization of silver nanoparticles through plant leaf stomata was completed. The group also investigated antibiotic transport, bacterial community assembly and profiles of ARGs in lettuce shoots and roots, rhizosphere soil, and bulk soil irrigated with antibiotics-containing water, using high throughput qPCR and 16S rRNA amplicon sequencing techniques. The group is continuing the study on interactions of infectious proteinaceous particles (prions, new groups of emerging contaminants) with soil geosorbents. This study aimed to understand environmental behaviors of chronic wasting disease prions and to develop novel cost-effective mitigation strategies. Molecular dynamics simulation capacity is being established to study interactions of amino acids and eventually peptides, poly peptides, and prions with aromatic carbon surfaces.

Outputs:

Organized the symposium titled Honoring the Contributions of Donald Sparks along with oral and poster sessions (organized by Ganga Hettiarachchi, Daniel Strawn, Donald Sparks and others); Published a review paper on trace elements in the environment; Published a review paper on fate and transport in environmental quality. Our group published 17 journal articles and gave 24 conference presentations.

Impacts

The scholarly products of our group provide important scientific information to scientists and other stakeholders to better manage soil and water resources, remediate environmental pollution, improve agricultural productivity, ensure food safety, and increase climate resilience of agricultural systems, all of which is key to agricultural sustainability and human health.

Publications

Peer-reviewed:

1. Alagele, S.M., S. Jose, S.H. Anderson, and R.P. Udawatta. 2021. Hydraulic lift: Processes, methods, and practical implications for society. *Agroforestry Systems* 95:641-657.

2. Heronemus, E., K.H.H. Gamage, G.M. Hettiarachchi, P. Parameswaran. 2021. Efficient recovery of phosphorus and sulfur from Anaerobic Membrane Bioreactor (AnMBR) permeate using chemical addition of iron and evaluation of its nutrient availability for plant uptake, *Sci. Total Environ.* 146850.
3. Judy, J.D., W. Harris, G. M. Hettiarachchi, A. C. Buchanan, K. R. Reddy. 2021. Mineralogy of particulate inputs and P-speciation and mineralogy of recently accreted soils within Everglades stormwater treatment wetlands, *Science of The Total Environment*, 781, 146740.
4. Li, Y., Livi, K.J.T., Arenberg, M.R., Xu, S., Arai, Y. 2021. Depth sequence distribution of water-extractable colloidal phosphorus and phosphorus speciation in intensively managed agricultural soils. *Chemosphere.* 286, 131665.
5. Pachepsky, Y., R. Anderson, T. Harter, D. Jacques, R. Jamieson, J. Jeong, H. Kim, K. Lamorski, G. Martinez, Y. Ouyang, S. Shukla, Y. Wan, W. Zheng, and W. Zhang. 2021. Fate and transport in environmental quality. *Journal of Environmental Quality*, 50(6), 1282-1289.
6. Pitumpe Arachchige, P.S., G.M. Hettiarachchi, C.W. Rice, L. Maurmann, J.J. Dynes, and T. Reiger. 2021. Chemistry and Associations of Carbon in Water-Stable Soil Aggregates from a Long-Term Temperate Agroecosystem and Implications on Soil Carbon Stabilization. *ACS Agric. Sci. Technol.* 1, 3, 173–181.
7. Rankoth, L.M., R.P. Udawatta, S.H. Anderson, C.J. Gantzer, and S. Alagele. 2021. Cover crop influence on soil water dynamics for a corn-soybean rotation. *Agrosystems, Geosciences & Environment* 4:e20175.
8. Shen, Y., E.T. Ryser, H. Li, and W. Zhang. 2021. Bacterial community assembly and antibiotic resistance genes in the lettuce-soil system upon antibiotic exposure. *Science of the Total Environment*, 778, 146255.
9. Shen, Y., J.A. Hamm, F. Gao, E.T. Ryser, and W. Zhang. 2021. Assessing consumer buy and pay preferences for labeled food products with statistical and machine learning methods. *Journal of Food Protection*, 84(9), 1560–1566.
10. Rhodes, G., Y.-H. Chuang, R. Hammerschmidt, W. Zhang, S.A. Boyd, and H. Li. 2021. Uptake of cephalixin by lettuce, celery, and radish from water. *Chemosphere*, 263, 127916.
11. Shen, Y., H. Li, E.T. Ryser, and W. Zhang. 2021. Comparing root concentration factors of antibiotics for lettuce (*Lactuca sativa*) measured in rhizosphere and bulk soils. *Chemosphere*, 262, 127677.
12. Singh, N., S. Kumar, R.P. Udawatta, S.H. Anderson, L.W. De Jongeand, and S. Katuwal. 2021. X-ray micro-computed tomography characterized soil pore network as influenced by long-term application of manure and fertilizer. *Geoderma* 385:Article114872:1-8.
13. Singh, N., S. Kumar, R.P. Udawatta, S.H. Anderson, L.W. DeJonge, and S. Katuwal. 2021. Grassland conversion to croplands impacted soil pore parameters measured using X-ray computed tomography. *Soil Sci. Soc. Am. J.* 85:73-84.
14. Song, E., K.W. Goyne, R.J. Kremer, S.H. Anderson, and X. Xiong. 2021. Certain soil surfactants could become a source of soil water repellency after repeated application. Special Issue: Nanostructure surfaces and Thin Films for Advanced Wetting Applications. *Nanomaterials* 11:2577 (1-15).
15. Strawn, S.G., G.M. Hettiarachchi. 2021. 50 years of articles in JEQ on trace elements in the environment, and future outlook. *J. Environ. Qual.* 50: 1266-1281.

16. Tomaszewski, E., E. Coward, and D.L. Sparks. 2021. Ionic strength and species drive iron-carbon adsorption dynamics: Implications for carbon cycling in future coastal environments. *Environ. Sci, Technol. Letters* 8(8): 719-724.
17. Xu, S., Martin, N.F., Matthews, J.W. and Arai, Y. 2022. Accumulation and release of organic phosphorus (P) from legacy P-affected soils to adjacent drainage water. *Environmental Science and Pollution Research*. In press

Media:

Advanced Photo Source 2021 Science Highlights. Altering the Fate of Phosphorus Fertilizer in Mildly Calcareous Soils

<https://www.aps.anl.gov/APS-Science-Highlight/2021-04-16/altering-the-fate-of-phosphorus-fertilizer-in-mildly-calcareous>

Training:

Together with beamline scientists (Qing Ma and Denis Keane) Dr. Hettiarachchi collected research data as part to APS Neutron and X-ray Scattering (NX) school while sharing our research work with the school participants July 20-22 (virtual)

Presentations/Abstracts:

1. Ansari, J., S.H. Anderson, M.P. Davis, F. Eivazi, and S. Bardhan. 2021. Role of land management practices on soil greenhouse gas (N₂O and CH₄) emissions in Missouri River Floodplains. International Association for Society and Natural Resources Conference Abstracts. 20-24 June, Portland, Oregon (virtual).
2. Ansari, J., S.H. Anderson, M. Davis, F. Eivazi, and S. Bardhan. 2021. Soil greenhouse gas emissions as affected by land management in Missouri River floodplains. p. 179. Soil and Water Conservation Society International Conference Abstracts, 26-28 July, Portland, Oregon (virtual).
3. Ansari, J., S.H. Anderson, F. Eivazi, M.P. Davis, and S. Bardhan. 2021. Soil greenhouse gas emissions affected by selected land management. 2021 American Society of Agronomy/Soil Science Society of America International Meeting Abstracts. 7-10 November, Salt Lake City, Utah.
4. Ansari, J., S.H. Anderson, F. Eivazi, and S. Bardhan. 2021. Soil enzyme activity affected by selected land management in Missouri River floodplain. 2021 American Society of Agronomy/Soil Science Society of America International Meeting Abstracts. 7-10 November, Salt Lake City, Utah.
5. Al-Awwal, N., S.H. Anderson, and M. El-Dweik. 2021. Adsorption of fluorescent labeled E. coli as affected by selected conservation buffer systems. p. 190. Soil and Water Conservation Society International Conference Abstracts, 26-28 July, Portland, Oregon (virtual).
6. Al-Awwal, N., S.H. Anderson, and M. El-Dweik. 2021. Selected conservation buffer system effects on adsorption of fluorescent labeled E. coli. 2021 American Society of

- Agronomy/Soil Science Society of America International Meeting Abstracts. 7-10 November, Salt Lake City, Utah.
7. Bradley, T., S.H. Anderson, K.S. Veum, E.B. Webb, and K.M. Clark. 2021. Regeneration of soil microbial, physical, and chemical properties in restored bottomland hardwood forest wetlands. 2021 American Society of Agronomy/Soil Science Society of America International Meeting Abstracts. 7-10 November, Salt Lake City, Utah.
 8. Conway, L.S., N.R. Kitchen, K.A. Sudduth, and S.H. Anderson. 2021. Modeling corn emergence uniformity with on-the-go furrow sensing technology. 2021 American Society of Agronomy/Soil Science Society of America International Meeting Abstracts. 7-10 November, Salt Lake City, Utah.
 9. Gamage, K.H.H., G. M. Hettiarachchi, P. Parameswaran, and S. Hutchinson. 2021. Phosphorus fertilizer and cover crop management affect sediment phosphorus speciation in no-till corn and soybean rotation. ASA-CSSA-SSSA International Annual Meeting, Salt Lake City, Utah. Nov. 7-10.
 10. Gamage, K.H.H., G. M. Hettiarachchi, P. Parameswaran, and S. Hutchinson. 2021. Recovered calcium based-phosphorus products from animal wastewater: Fate and behavior in soils. ASA-CSSA-SSSA International Annual Meeting, Salt Lake City, Utah. Nov. 7-10.
 11. Hettiarachchi, G.M., J. Weeks, and J. Pierzynski. 2021. Responsible fertilizer phosphorus management through mechanistic understanding of phosphorus reaction pathways in soils. American Chemical Society Fall Meeting, Hybrid, Atlanta, Georgia, Aug. 22-26.
 12. Kaur, S. and G.M. Hettiarachchi. 2021. Zinc source drives soil Zn diffusion, extractability, and uptake by wheat plants. ASA-CSSA-SSSA International Annual Meeting, Salt Lake City, Utah. Nov. 7-10.
 13. Kaur, S. and G.M. Hettiarachchi. 2021. Tracking diffusion and extractability of different Zn fertilizer sources in soil. ASA-CSSA-SSSA International Annual Meeting, Salt Lake City, Utah. Nov. 7-10.
 14. Li, H., W. Wang, G. Rhodes, W. Zhang, and B.J. Teppen. 2021. Sorption of perfluoroalkyl carboxylic acids by soils: Contribution of partitioning in soil organic matter and cation-bridging interaction. ASA-CSSA-SSSA International Annual Meeting, Salt Lake City, UT, November 7-10 (poster presentation).
 15. Li, Y., Livi, K.J.T., and Y. Arai. 2021. Depth sequence distribution of water extractable colloidal phosphorus and its phosphorus speciation in intensively managed agricultural soils. Annual Soil Science Society of America Meeting.
 16. Mendis, S.S., R. Udawatta, S.H. Anderson, and R. Cordsiemon. 2021. Cover crop effects on soil moisture dynamics of a corn cropping system. p. 66. Soil and Water Conservation Society International Conference Abstracts, 26-28 July, Portland, Oregon (virtual).
 17. Salceda, M., R.P. Udawatta, S.H. Anderson, and S.S. Mendis. 2021. Trees and grasses on nitrogen and phosphorus filtration from shallow groundwater on a rotational grazing hillslope landscape. Scaling Up Agroforestry for Carbon Drawdown. Abstracts of the 17th North American Agroforestry Conference. 28 June – 2 July, Savanna Institute Madison, Wisconsin, USA (virtual).

18. Schwab, A.P., G.M. Hettiarachchi, A. Pandey, and D. Ming. 2021. Synchrotron spectromicroscopy analyses of amorphous phases in Hawaiian palagonitic tephra. ASA-CSSA-SSSA International Annual Meeting, Salt Lake City, Utah. Nov. 7-10.
19. Strawn, Heron, Cade-Menun, Dobre, Deval, Piaskowski, Crump, Gasch. 2021. Soil Phosphorus Speciation and Availability in Meadows and Forests in Alpine Lake Watersheds with Different Parent Materials. Soil Science Society of America annual meeting, Salt Lake City, UT.
20. Svedin, J.D., C. Ransom, K.S. Veum, S.H. Anderson, and N. R. Kitchen. 2021. Integrating soil biological properties to improve corn fertilizer recommendations. 2021 American Society of Agronomy/Soil Science Society of America International Meeting Abstracts. 7-10 November, Salt Lake City, Utah.
21. Szerlag, K. D., P. Northrup, and D.L. Sparks. 2021. Advances in the use of synchrotron-based spatially resolved imaging and spectroscopy to speciate phosphorus in soils. Soil Science Society of America Meeting, Salt Lake City, Nov., 2021.
22. Tomaszewski, E. E. Coward, and D.L. Sparks. 2021. Ionic strength and species drive iron-carbon adsorption dynamics: Implications for carbon cycling in future coastal environments. American Chemical Society National Meeting.
23. Yuan, Q., W. Zhang, H. Li, and J. Bartz. 2021. Effects of transitional metals on environmental persistence of chronic wasting disease prions. ASA-CSSA-SSSA International Annual Meeting, Salt Lake City, UT, November 7-10 (virtual oral presentation).
24. Zhang, W., R. Benedict, and H. Li. 2021. Pollution mitigation prospects of pyrogenic carbon in soils. ASA-CSSA-SSSA International Annual Meeting, Salt Lake City, UT, November 7-10 (oral presentation).