Soil Chemistry and the One Health Initiative: Introduction to the Special Section

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Abstract
Population growth and technical and social changes have always exerted pressure on environmental quality. However, we are experiencing unprecedented change in the rate and scale of human impacts on the environment. The One Health Initiative recognizes that improving the quality of life for humans and other animal species requires a holistic and integrated framework to seek multidisciplinary solutions to global environmental challenges. This special section is designed to elucidate the connections among soil health, environmental quality, food safety and security, and human health. Soil chemistry plays a central role in food production and the protection of human health. Chemical reactions between nutrients or contaminants and soil solids, and the composition of the soil solution and the atmosphere, influence crop growth as well as the quality of our food, air, and water. This collection of nine papers brings together studies that highlight how soil chemical constituents, properties, and reactions can be examined or managed using a multidisciplinary approach to move toward a more efficient, sustainable, nutrient-rich, and low-contaminant food production system that affords protection of soil, water, and human and animal health. We believe that studies such as these are needed to maintain and enhance environmental quality through interdisciplinary scientific approaches for human, animal, and environmental health outcomes.

Core Ideas
• One Health Initiative links soils to human, animal, and environmental health.
• Interdisciplinary soil chemistry studies protect and enhance environmental quality.
• Environmental quality will benefit from a holistic view of environmental processes.

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maintain the biodiversity and ecosystem services, and contribute to human health (McBratney and Koch, 2014). McBratney and Koch (2014) state seven specific soil functions: (i) biomass production; (ii) storing, filtering, and transforming of nutrients, substances, and water; (iii) acting as a biodiversity pool; (iv) acting as a physical and cultural environment; (v) acting as a source of raw materials; (vi) acting as a carbon pool; and (vii) acting as an archive of geological and cultural heritage. Robinson et al. (2009) categorized the ecosystem services provided by soils as supporting, provisioning, regulating, and cultural services (Table 1). These broad frameworks share similarities and provide a guide to help ensure that a holistic view of soil environmental quality is taken in the assessment of how agricultural management systems affect ecological processes. Soil chemistry sits at the core of these fundamental functions.

Keith et al. (2016) propose four broad themes for soil research under the umbrella of the One Health Initiative: (i) relationships between soil stewardship practices and health metrics at farm and landscape scales; (ii) mediation of exposure to chemical contaminants by the practice of soil stewardship to lessen contamination through the food chain (e.g., uptake by crops of veterinary pharmaceuticals via manures) and transport to air and water; (iii) mediation of the dynamics of pathogenic organisms important to crop, animal, and human health by soil stewardship practices, including landscape configuration; and (iv) correlations and tradeoffs between ecosystem services and health metrics at landscape and regional scales. We have modified the diagram shown in Keith et al. (2016) to illustrate how the soil stewardship practices discussed in this “Soil Chemistry and the One Health Initiative” special collection can lead to better awareness of how ecosystem services affect soil health, environmental quality, food safety and security, and human health (Fig. 1).

The aim of this special section is to demonstrate the need for well-designed interdisciplinary studies with well-thought-out methods that explicitly include the linkages between soil chemistry and human and animal health to address the complex environmental quality issues that we currently face. The growing global population combined with increasing economic development is likely to further escalate environmental stresses. In addition to population pressure, climate change is likely to alter soil and ecological processes, which will further affect the environment. Implementing holistic approaches to address environmental quality issues will be needed to maintain or improve global human, animal, and soil health.

**Overview of the Special Section Papers**

In the section below we highlight the key findings from the nine papers presented in this JEQ Soil Chemistry and One Health Initiative special section. For organizational purposes, we have grouped the papers under two broad subject headings based on the categories of ecosystem services (Table 1): (i) regulating studies and (ii) supporting studies.

**Regulating Studies: Roles of Soil Chemistry in Influencing the Impacts of Antibiotics, Pharmaceuticals, Herbicides, and Toxic Trace Elements**

The livestock sector inhabits 30% of Earth’s ice-free surface, uses one-third of the freshwater supply, and accounts for 40% of the global agricultural gross domestic product of the planet (Herrero et al., 2013). The United States has an estimated 2.2 billion heads of livestock and poultry, which produce 1.1 billion metric tons of fresh weight manure annually (Zhang and Schroder, 2014). Land spreading of manure has been long recognized as a management approach to recycling valuable plant nutrients and as a method of disposal (Troeh and Thompson, 1993). Environmental quality issues have traditionally focused on reducing excessive nutrient release into the environment (Carpenter et al., 1998; Kleinman, 2005). However, recent concern has been raised about the presence of veterinary antibiotics in manures and the subsequent rise of antibiotic resistance (Xie et al., 2018).

Le et al. (2018) conducted a field plot-scale study of whether subsurface manure injection, conceived as a method to reduce the loss of plant nutrients, could also reduce the surface runoff of the antibiotics pirlimycin, tylosin, chlortetracycline, and sulfamethazine, compared with surface application of manure. On Days 0, 3, and 7 after application, a 70-mm h⁻¹ simulated rainfall was used to collect runoff from the plots. Subsurface injection reduced runoff lost from 47 to 88%, with an average of 61%, suggesting that subsurface injection would substantially reduce surface runoff. Water solubility of the antibiotic determined the partitioning of the compound between runoff sediment and runoff water, with chlorotetracycline occurring in the sediment and the other three antibiotics present mostly in the runoff water. An additional important finding was that antibiotic runoff 3 d after application of a simulated rainfall was reduced by a factor of 25 (range of 9 to 45) for surface application of manure and 23 (range of 11 to 43) for subsoil injection compared with runoff on Day 0. Thus subsoil injection would likely result in less antibiotic runoff than surface manure application. However, the authors state that further studies are needed on how subsurface injection affects the downward transport of antibiotics to groundwater before best management recommendations can be made.

Chen et al. (2018) conducted a greenhouse study to assess how cattle manure with and without composting treatment affects levels of sulfamethazine, chlortetracycline, and tyllosin in soils planted to lettuce (Lactuca sativa L.), radish (Raphanus sativus L.), or broccoli (Brassica oleracea L. var. italica) seedlings. Manure from cattle fed with feed containing antibiotics was collected for the “antibiotic manure” treatment and manure from cattle without antibiotics in their feed was the “control manure.” Subsamples of both raw manures were composted for 42 d to generate the composted version of the manure samples. The antibiotic concentrations in all compost-amended soils were below detection limits, whereas the raw manure contained detectable
antibiotics. Comparison of the bulk soil with rhizosphere soil showed differential effects depending on the antibiotic compound. Sulfamethazine was not detected in the rhizosphere soil, chlortetracycline was about two times lower in the rhizosphere soil, and tylosin content was similar between the bulk and rhizosphere soils, suggesting that plant–microbe interactions are a factor in the dissipation of sulfamethazine and chlortetracycline. The antibiotic resistance genes tet(W) and intI1 were significantly higher in the soils amended with manure or compost than in a fertilizer-amended control soil. This study suggests that composting of manure is likely to reduce the input of antibiotics to soils to which manure is applied.

Ashworth et al. (2018) report on a 12-yr cropping systems study investigating the use of poultry litter, different crop (soybean [Glycine max (L.) Merr.], corn [Zea mays L.], and cotton [Gossypium hirsutum L.]) rotations, and tillage operations on soil chemical and biodiversity. The results showed that application of poultry litter significantly increased soil N by 13%, P by 72%, and K by 56% compared with the effects of wheat (Triticum aestivum L.) and hairy vetch (Vicia villosa Roth.) cover crops. Analysis indicated that earthworms were associated with high nutrient amendments (poultry litter) and lower pesticide-intensive rotations such as the soybean and corn rotations. Poultry litter amendment also affected microbial community composition. This study shows that poultry litter amendment can increase soil fertility levels and crop yields and promote greater soil biodiversity.

Water quality is a critical issue for human health, and the Clean Water Act of 1972 established regulations regarding the discharge of wastewater into the environment and provided grant funding for the construction of wastewater treatment facilities (USEPA, 2004). Currently, ~16,000 municipal treatment facilities are in operation, serving >75% of the US population (USEPA, 2004). The traditional pollutants reduced in treatment facilities have been pathogens, nutrients, and oxygen-demanding substances (Spiro and Stigliani, 1999). Two papers in this section address the ability of Fe and Al (oxy)hydroxides to remove arsenate from wastewater and the fate of antibiotics present in effluent on discharge.

Vasques et al. (2018) investigated the use of Fe and Al coprecipitates of Fe/Al in molar ratios of 100:0, 80:20, and 60:40 to treat water containing As at concentrations of 50 and 500 mg L$^{-1}$. X-ray diffraction analysis indicated the presence of maghemite, magnetite, lepidocrocite, and goethite in the precipitates formed from Fe(II) and hematite and ferricydrate in the precipitates formed from Fe(III). In the presence of Al, gibbsite and bayerite formed, as well as some Fe minerals with isomorphically substituted Al. All coprecipitates removed >98% of the As present in test solutions, indicating the As removal was not sensitive to the Fe/Al molar ratio of the coprecipitate. The treatments were able to meet the effluent discharge threshold of 0.5 mg As L$^{-1}$; however, the drinking water threshold of 10 μg L$^{-1}$ was met only for the 50 mg As L$^{-1}$. This study demonstrates the effectiveness of Fe and Al (oxy)hydroxides to remove As from water.

Franklin et al. (2018) investigated the fate of antibiotics present in wastewater effluent. Most municipal treatment plants are not able to completely remove pharmaceuticals from the waste stream, leading to low concentration of these compounds in the environment. This study investigated discharge to soil as a means of natural filtering to curb or prevent the entry of antibiotics into groundwater. The range of antibiotics in the effluent was 11 to 22,000 ng L$^{-1}$, 5 to 740 ng kg$^{-1}$ in the soil, 0.14 to 660 ng L$^{-1}$ in the groundwater. The attenuation of antibiotics in the groundwater by approximately three orders of magnitude suggests that soil filtering could be an effective means of reducing environmental exposure to antibiotics. However, concern still exists that even at these low antibiotic concentrations, there may be chronic health effects for humans and animals, as well as the potential of the development of antibiotic resistance.

Jimmo et al. (2018) evaluated the risks associated with the use of two herbicides (triclopyr and imazapyr) for vegetation control in power transmission rights-of-way. Soils were sampled 1, 30, and 365 d after spraying at four sites, and, more intensively, after 0.1, 1, 3, 7, 14, 21, 30, and 365 d at a fifth site. Soils were also collected for soil toxicology tests to determine dose–response curves. Dissipation of triclopyr was much more rapid, with 50% dissipation by Day 1 compared with 16 d for imazapyr. The soil
toxicological testing of both triclopyr and imazapyr showed minimal effects on soil invertebrates typically found at the study sites. Overall, risk assessment using weight of evidence and toxic exposure ratio methods indicates that the use of triclopyr presents less potential risk due to its relatively rapid initial dissipation, low risk to soil invertebrates, and rapid nontarget vegetative recovery. This study demonstrates how ecosystem health can be part of the risk assessment process in evaluating management regimes for rights-of-way.

Ferreira et al. (2018) investigated the influence of pH on Cs adsorption to vermiculite and the interlayer collapse on Cs adsorption. Radioactive $^{137}$Cs is a primary isotope released from nuclear power plant incidents and contaminates the soil in the regions affected by a nuclear accident. The study indicates increasing Cs adsorption to vermiculite as pH increases to about pH 6 and a plateau at pH 9. The pH envelope showed that even at pH 1 there was adsorption, suggesting that even at highly acidic environments, vermiculite exhibits high affinity for Cs. X-ray diffraction analysis indicated a d-spacing decrease from 13.1 to 11.0 Å when vermiculite is equilibrated with Cs. This collapse suggests that removal of Cs for remediation purposes after radioactive contamination is likely to be difficult.

Supporting Studies: Roles of Soil Chemistry for Fortification and Management of Cropping Systems

Boldrin et al. (2018) investigated the ability of different Brazilian wheat cultivars to increase their Se content. Selenium is an essential element for animals and humans, and the average human intake may not meet the daily Se requirement of 55 to 200 µg. Biofortification of crops to enhance Se content may be one approach to address Se shortfalls in dietary intake. Approximately 30 to 50% of the Se is translocated into the grain of the plants, suggesting that biofortification of wheat is likely to be effective in increasing Se dietary intake. The variation in translocation efficiency highlights the need for careful selection of the cultivars in a biofortification program. The genes involved in Se uptake and assimilation were not identifiably different between the cultivars in higher and lower Se-accumulating groups. The study demonstrates that biofortification with low levels of Se added to wheat crops will likely enhance the nutritional value of wheat grain and improve the health status of those whose typical diets have lower-than-recommended daily intake of Se.

Beard et al. (2018) investigated the role of N fertilization and crop species on the formation of raindrop-induced soil crusting in the semiarid US Pacific Northwest. Silica ($\text{SiO}_2$) accumulation has been linked to soil pan formation through the polymerization and deposition of $\text{SiO}_2$, which is affected by wet–dry cycles and soil acidification processes. One approach to lessen the formation of soil crusts is to reduce the recycling of Si to the soil surface by growing crops with reduced Si uptake. Wheat, the dominant crop in the Pacific Northwest, accumulates 10 times more Si than canola ($\text{Brassica napus L.}$). In the reported study, two soil incubations were conducted to determine the effect of four levels of aqueous $\text{H}_2\text{SiO}_3$ addition and wheat and canola crop residue on soil crust formation. The $\text{H}_2\text{SiO}_3$ treatments increased soil crust formation, but there was no significant difference in crust formation between the two crop residues, suggesting that crop management strategies will require multiple rotation cycles to see reduction in crust formation. A more diversified cropping system, such as introducing canola to a monoculture wheat system, will likely lead to a more sustainable system that benefits soil health and may provide human health benefits through greater availability of vegetable-based oils.

Summary

Critical environmental quality issues are complex problems that can best be approached with an interdisciplinary collaboration between soil science researchers and those in other disciplines such as ecology, plant science, animal health, and human health. Looking to the future, holistic research studies that directly link soil science with broad animal and human health concerns are likely to produce results that can directly benefit environmental sustainability and human health. The recent One Health Initiative provides one example how such an approach could be used. We hope that the studies in this special section provide a glimpse of how soil chemistry studies could address current and emerging environmental quality issues to achieve solutions that address human, animal, and soil health concerns. Consideration of these concerns and taking interdisciplinary research approaches to tackle challenges that have so far been the subject of single-disciplinary research approaches are necessary to achieve long-term environmental and ecological sustainability.

References


