This month's library is devoted to worms. You may know that worms are great for soil. They help to aerate the soil and give it structure. The worms eat the soil and the worm poop aka worm castings are highly valued. The castings help to improve structure and also help to make the nutrients in the soil more available. This happens because of something magical about the worm gut and the worm poop- almost like the biosolids. But that is not why the library is devoted to worms. The library is devoted to worms because worms play an additional critical role- that of transfer of contaminants across the food chain. Worms eat dirt and if the dirt contains contaminants a portion of those contaminants may be taken up into worm tissue. Another portion will exist in the worm in the form of the soil that fills its guts. You are likely familiar with the saying about the early bird. Birds eat worms and then bigger birds and other animals eat the birds that eat the worms. If the worms and the soil in the worm gut are contaminated, the worm becomes a critical point for contaminants in the soil to enter the food chain. The contaminants we are focused on this month are microconstituents.

Now there are other ways that microconstitutents in soils can cause harm, many other potential pathways. People eating soil directly for example. In this particular case we know that this is really an irrelevant pathway. These compounds come from our homes and are in our everyday products. The pathway from the prescription bottle to the human is much more important and direct than from soil to human. The plant pathway is also a potential. This was the most important pathway for cadmium in the 503 risk assessment process. Again, with these compounds research has shown virtually no plant uptake. Risk to soil microbes is also a concern. And again, as has been covered in the library, studies where biosolids have been added to soil show no disruption of microbial activities. In fact, there are some indications of increased microbial diversity when biosolids are used instead of synthetic fertilizers.

That leaves us with the worms and the worm pathway for ecosystem transfer.

The first paper in the library this month is an oldie but goodie. Written just after I graduated from college. The paper focuses on metal concentrations in worms collected from biosolids amended soils. This was included to show that the importance of the worm for ecosystem transfer is not a new concept. It is also included because it talks about the concentration of metals in the worm tissue in comparison to the concentrations in the soil. If the concentration in the worm tissue is greater than the concentration in the soil, the bioaccumulation factor or BAF is greater than 1. When the BAF is greater than 1, there is a higher potential for the contaminant to concentrate as it is transferred up the food chain. In fact in this study, the authors saw that cadmium had a high BAF with 100 ppm Cd in the worms collected from soil with only 2 ppm Cd. Remember that this study was conducted long before pre treatment regulations went into effect- so it is here as an early example of earthworms as indicators not as a sign that biosolids contaminant worms with cadmium.

The second study is the really critical one in the library. Here authors looked at earthworm uptake of 4 pharmaceuticals (carbamazepine an anti seizure drug, diclofenac an NSAID or non steroidal anti inflammatory drug, fluoxetine an antidepressant aka

Prozac, and orlistat, an anti obesity drug. The authors added radioactive compound to soil (no biosolids here) in a lab setting and then added the worms. The C^{14} labeled compounds allowed the authors to trace the path of the C^{14} during the study. Compounds were added to the soil at concentrations ranging from 39-80 ppb wet weight-likely about 1.5 times that on a dry weight basis. As a basis for comparison, the concentration of the antidepressant in biosolids has been reported as ranging from below detection to about 170 ppb. The worms were depurated – meaning they were allowed to poop out the soil in their guts, prior to analysis. What the authors found was lower BAF then had been predicted using chemical models. They found 'complete' elimination of carbamazepine and fluoxetine and partial elimination for orlistat and diclofenac, with concentrations of both of the latter compounds decreasing in the worms very gradually. In other words, the study suggests a relatively low potential for ecosystem transfer.

The third study caused quite the stir in its' day. It was the first worm study on these compounds. The authors sampled worms from a field that had received biosolids, one where animal manure had been applied and a third where conventional fertilizers had been used. While the authors concluded that biosolids would decimate the worm population, a closer look at the data (Table 1) shows that most compounds are non detects across all three soils. Others, including indole, a fragrance compound, are present in worms collected at all three sites. Galaxolide, another fragrance compound was detected only in biosolids amended soils and worms but shows inconsistent bioaccumulation factors. Bioaccumulation factors are shown in table 2 and indicate that triclosan and cholesterol are the two compounds where the values truly appear to be greater than one. Perhaps the broad scale use of these compounds are a greater concern than the use of biosolids. Perhaps also pigs really are wearing lipstick, scented lipstick at that.

For the 4th study we move onto a recent earthworm study with Robert Hale as a co-author. Here the focus is on PBDEs or flame retardants. Here soils and worms were sampled from a long term application site in MD, agronomic applications since the 1980s every 2-3 years. The authors sampled a range of critters in addition to the worms but here I am focusing on the worms and the soils. The authors also included samples of aged biosolids but it is not clear to me how representative those aged biosolids could have been with the long history of application. They found that the soil was higher in PBDEs than the biosolids and also that the soil concentrations were generally higher than the worms, in other words a BAF <1. They also noted a trend of higher worm accumulation of the lower weight PBDEs than the higher weight or less soluble compounds. Perhaps most importantly they noted much lower availability than was found previously in laboratory studies. No plant uptake of the PBDEs was observed. The library closes with an earlier study on worm uptake of PBDEs where highly contaminated biosolids (from textile manufacturing) as well as soils contaminated with PBDEs from river flooding were tested along with corresponding worms. This study found generally contradictory results from the recent Hale study with higher accumulation of the higher weight PBDEs. This is included to fill out the library and as a way to show that answers on this on not so clear yet. Another study in a previous library in fact found that birds were the most sensitive species for TCC uptake. That study (Snyder et al., 2013). In fact, that study noted the importance of additional research on the earthworm to predator

pathway. From the initial findings however, it does not seem like the earthworm pathway for microconstituents will be a deal breaker.