



Information Update:

Microconstituents in Biosolids: Current State of Knowledge

May 12, 2011

Introduction

The increased attention being paid to microconstituents (traces of synthetic chemicals from consumer products and daily activities) in the environment has led to questions about the contribution from applications of biosolids to soils. Which microconstituents end up in biosolids and in soils? What are their fates? What are their impacts? Research to address these questions ramped up in the mid-2000s, and major updates on the science-to-date were published in 2010.

The variety of different chemicals in pharmaceuticals, personal care products (PPCPs), and other consumer products react in different ways in the wastewater treatment, biosolids treatment, and beneficial use processes. While many are degraded or volatilized, some adsorb to the solids and fractionate in large proportions into wastewater solids. Because more than half of the wastewater solids produced in the U. S. are applied to soils, the presence, fate, and impacts of these microconstituents in biosolids are of interest to producers and managers of biosolids products, users of biosolids (farmers, gardeners), and the general public.

Historic perspective

The presence in biosolids of traces of myriad synthetic chemicals is not new. For more than 30 years, researchers interested in the use of biosolids on soils have assessed the presence, fate, and significance of legacy organic compounds (e.g. PCBs) and priority pollutants (e.g. PAHs, pesticides). In the early 2000s, EPA conducted an extensive survey and risk assessment regarding dioxins in biosolids that resulted in a decision not to regulate them.

That prior research frames the current research on “emerging” contaminants and other microconstituents in biosolids. Trace synthetic chemicals have been in biosolids as long as the chemicals have been used in commercial products, but they have only recently been detected and focused on. In the past, PCBs and dioxins presented the greatest concern because of their persistence in the environment, as well as their significant, known, toxicity.

As researchers have begun to focus on microconstituents in biosolids, they have looked for chemicals in common use in consumer products – high production chemicals – that are considered of concern for endocrine disruption, mutagenic, or other toxicity, and which may be persistent. In 2006, Rolf Halden’s research team (Heidler et al.) at Johns Hopkins University published research focused on the anti-microbial triclocarban (TCC), finding it to be ubiquitous at up to 50 mg/kg in the biosolids they tested. TCC, like its even more common cousin triclosan (TCS), is persistent, partitions to biosolids, and has been shown to have negative biological impacts in some tests.

The evolution from assessing presence to understanding fate and significance

At the 2004 “Sustainable Land Application” conference – a once-a-decade review of the science of biosolids recycling, Xia et al. reported that there were many unknowns about the presence, fate, and significance of microconstituents of emerging concern in biosolids.

Soon after, there were several key publications focusing on the *presence* of microconstituents in biosolids. These relied on advances in detection technologies and procedures. Biosolids are a complex matrix, far more challenging for analysis than water. USGS scientists (Kinney et al.) led research on the presence of diverse PPCPs in biosolids (see <http://toxics.usgs.gov/highlights/biosolids.html>). U. S. EPA added microconstituents to the long list of analytes in its Targeted National Sewage Sludge Survey (TNSSS), completed in 2009. Microconstituents were found in all samples tested, some more often than others. So, just as diverse microconstituents are found in aquatic environments downstream of wastewater treatment plants, so some chemicals appear regularly in biosolids, generally in parts per billion and, with some chemicals, in low parts per million (mg/kg).

The next step has been to study their *fate*. Topp et al. (2009) looked at land application of biosolids on agricultural fields in Ontario, finding that “PPCPs are detected in tile drainage and in surface runoff, sometimes months after application...” They noted differences in concentrations caused by different land application practices (e.g. liquid vs. cake application), but concluded that “maximum concentrations of PPCPs detected in effluents [tile drainage] were generally far below toxic thresholds for a variety of endpoints drawn from the literature.” Other research clearly indicated that some microconstituents, such as nonylphenols, degrade within days in aerobic soils, whereas others, like TCC and TCS, appear to be more persistent.

Kinney et al. (2008) found trace organic contaminants in the tissues of earthworms living in soils amended with biosolids or swine manure. In 2010, Wu et al. reported on finding uptake of PPCP chemicals into soybean plants in a greenhouse study. Both papers generated some media attention. But several researchers who had studied trace contaminants in biosolids for decades noted that the experimental design of the Wu study included spiking of fresh PPCP samples into the soil, which, in past experiments, has also yielded higher uptake values than are found in field conditions with typical biosolids application scenarios.

Still, even minute levels of uptake into food plants raises the question of potential impacts to human health. In response to that concern, *context* is important. Many of these particular chemicals (PPCPs) are in use in products with which humans have direct contact in much higher doses than would make it through the biosolids-soil-human or biosolids-soil-plant-human pathways. For example, TCS is in one line of toothpastes at a concentration of 0.3% (3000 mg/kg). In comparison, a typical land application scenario would result in soil concentrations of less than 50 parts per billion (.05 mg/kg), and the Wu et al. worst-case experiment found maximum concentrations of TCS in plant tissues of 0.1 mg/kg. Clearly, biosolids-borne TCS is not a significant relative risk compared to direct use of the toothpaste, if TCS is found to be a risk at all. (Currently, FDA states “Triclosan is not currently known to be hazardous to humans... FDA does not have sufficient safety evidence to recommend changing consumer use of products that contain triclosan at this time.”) Wu et al. and others have also found that TCS and TCC decompose in soil at a moderate rate.

Other studies on the *fate* of microconstituents have focused on the impacts of wastewater and biosolids treatment processes. Buyuksonmez and Sekeroglu (2005) found significant degradation during composting of biosolids. Furlong et al. (2010) tracked the concentration of estrogenic activity as

wastewater solids passed through different stages of wastewater and solids treatments. Hydromantis (2010) conducted a similar evaluation of the effectiveness of various solids treatment processes in reducing concentrations of microconstituents in biosolids. Biological treatments, including composting, were the most effective of the processes leading to beneficial use. “The ability of a combination of anaerobic digestion, followed by dewatering and composting, for example, might provide a means of reducing more of the ESOC [emerging substances of concern].”

Hundal et al. (2009) evaluated, in a field study, the fate – as well as the *impacts* – of several microconstituents in Chicago’s long-term biosolids land application program. “The data suggest limited mobility of biosolids borne TCC, TCS, total PBDEs [flame retardants], and 4-NP [nonylphenol] in biosolids-amended soils. Although the concentrations of TCC, TCS, 4-NP, and total PBDEs in soil were greater in the biosolids-amended plots than in the Control plots, the contaminants had no detrimental effects on the soil biota. Indeed, microbial community studies showed that the microbial populations were more diverse and much more biologically active in the biosolids-amended plots than in the control plots.”

The state of the science, 2010

Two literature reviews on the current state of the scientific understanding of microconstituents in biosolids were published in 2010.

The first, completed for the Water Environment Association of Ontario (WEAO), was an update of their earlier 2001 report. This report sorts a wide variety of families of chemicals into groups based on how much is known about their presence, fate, and impacts in biosolids land application scenarios. Thus, for example, linear alkylbenzene sulphonate surfactants (LAS), which are present in relatively high concentrations in biosolids (mg/kg levels), are known to degrade quickly in aerobic soils and are considered a minimal potential risk, which puts them in “Group I.” Other “Group I” families include phthalates, hormones, sterols, radionuclides, and polyaromatic hydrocarbons (PAHs). Enough is known to be able to say that these chemicals are unlikely to present any risk at the levels they are typically found in biosolids. “Group II” families are those for which additional research is recommended; they include pharmaceuticals, bisphenol A, brominated flame retardents, perflourinated compounds, and several others. For these, not enough is known about some of the key elements of potential risk: fate, mobility in soils, persistence in soils, and toxicity of trace concentrations to soil and other organisms.

The second literature review was completed for the Water Environment Research Foundation (WERF). It provides a similar summary of what is known and what is not yet known about the occurrence, mobility, persistence, bioavailability, and toxicity of various microconstituents. The review found that there is now a high level of knowledge regarding the occurrence of a wide variety of microconstituents in biosolids, and, for most, there is a reasonably high level of understanding of their mobility. For some, we know enough about persistence, bioavailability, and human toxicity at the typically very low concentrations found in biosolids to assist in assessing human risks. But more research is needed to understand any potential risk of impacts to other environmental receptors.

What does this mean for biosolids management?

As long-experienced University of Florida researcher George O’Connor noted in 2009, “All chemicals added to soils are subject to the same reactions/processes, including solid phase retention/release, degradation, bioaccumulation, volatilization, runoff, and leaching. The reactions/processes of organics have been studied for decades and the corresponding risk to human and environmental health assessed/estimated. Examples of organic chemicals so studied include pesticides, priority pollutants,

and others with chemical and physical properties similar to many of today's 'emerging chemicals of concern.'" As with those chemicals that have long been studied, the chemicals that would present the highest level of concern are persistent, bioaccumulative, and relatively high in toxicity (at least to some organisms). It is likely that there are relatively few, if any, microconstituents in biosolids that have all of these features and thus would be of significant concern. Research to date supports this conclusion.

Biosolids land application as a tool for managing microconstituents

One foundational premise of biosolids land application is that soil has an assimilative capacity, due, in part, to the concentrations of diverse biota, which results in decomposition of contaminants. The goal of a land application system is to apply biosolids at a rate at or below this capacity, which avoids build up of contaminants. Soil also binds (adsorbs) other contaminants, such as trace elements (heavy metals), making them less bioavailable; for some trace organic chemicals, this mechanism applies.

It is inevitable that society will send at least some synthetic chemicals into waste streams. The ultimate impacts of these microconstituents may depend on where they end up in the environment. Overcash, Sims, Sims, and Neiman (2005) emphasize that "these terrestrial systems [soils] have orders of magnitude greater microbial capability and residence time to achieve decomposition and assimilation compared with aquatic systems." As wastewater treatment is evaluated for its ability to deal with microconstituents, one premise should be that it is acceptable to encourage fractionation of contaminants to the solids, where further treatments and application to soils appears to usually degrade or bind them.

Future research will continue to look closely at the presence, fate, and impacts of particular microconstituents applied to soils via biosolids and other residuals. But, in addition, there is increasing research into direct measures of impacts that biosolids mixtures may or may not have on sentinel organisms. This *bioassay* approach is gaining interest as a tool for more efficiently answering the question "Does it matter that there are parts per billion of several chemicals in a particular biosolids product applied to soils?" So far, in general, bioassays evaluating the effects of biosolids on sensitive organisms have not shown negative biological impacts (McCarthy, 2010).

What biosolids managers can do when treating and applying biosolids

Research to date does not suggest significant risk to human health or the environment from microconstituents in biosolids applied to soils. The best way to address any *potential* concerns and uncertainties is to follow regulatory requirements and best management practices, including:

- Maintain strong industrial pretreatment programs and evaluate and address potential sources of unusual contaminants that could enter the wastewater facility's influent in large quantities.
- Process biosolids with multiple processes, especially biological processes, if possible. Different processes lead to decomposition of different microconstituents; aerobic biological processes (e.g. composting) have been shown to be most effective.
- Consider completing a representative sampling and testing of your biosolids product(s) for sentinel microconstituents for comparison to other research findings.
- Apply biosolids in accordance with agronomic rates, which limits the total mass of microconstituents, while providing the optimum level of benefits.
- Maintain setbacks from surface and groundwater, which keeps microconstituents out of the more sensitive aquatic environment.
- Apply biosolids to aerated soils, and incorporate whenever possible. This aids in natural degradation of microconstituents.
- Share information with customers and the public regarding this topic.

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The North East Biosolids and Residuals Association (NEBRA) is a 501(c)(3) non-profit professional association advancing the recycling of biosolids and other organic residuals in New England and eastern Canada. NEBRA membership includes the environmental professionals and organizations that produce, treat, test, consult on, and manage most of the region's biosolids and other large volume recyclable organic residuals. NEBRA is funded by membership fees, donations, and project grants. Its Board of Directors are from MA, ME, NH, VT, and New Brunswick. NEBRA's financial statements and other information are open for public inspection during normal business hours. For more information: <http://www.nebiosolids.org>.