Appendix D

Biosolids

Land Application of Treated Wastewater Byproducts

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January, 2021

TMACOG

Toledo Metropolitan Area Council of Governments

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I. Introduction

Land application of biosolids and other beneficial reuses of waste are the only viable options for long term sustainability of the wastewater system.

Where there are humans, there is a need for management of human waste. Humans add their waste to water and we dirty a lot of water: washing dishes, taking showers, and flushing toilets. To restore wastewater to clean, reusable condition, we need to separate out the solids. The solid materials separated from water is called sludge. The solid materials that remain after sludge has been treated are called biosolids. Because water treatment generates a lot of sludge in the world, and because much of it is nutrient-rich materials, people have come up with beneficial uses for the treated sludge. This paper discusses how sludge is treated to create safer biosolids, how biosolids may be used in land applications, provides an overview of the science and regulations, and proposes further research.

II. Biosolids Treatment and Processing

In 2016, about 7.1 million dry tons of biosolids were produced (Snyder & Associates, Inc., 2019). After production, biosolids need to be disposed of or reused. The most commonly used practices around the northwestern Ohio region are landfill disposal and land application. Reuse strategies can also include bioenergy and some other innovative strategies.

In Michigan and Ohio, state regulators recognize wastewater treatment plants (WWTP) as the preferred method of sewage treatment over onsite wastewater treatment such as home sewage treatment systems or package treatment plants. Increasingly, property that is close to a sewer line is required to connect to it for proper treatment of sewage.

To ensure biosolids are up to the U.S. EPA standard for land application (see "Federal, State and Local Regulations" on page 8), they must go through one or a combination of treatments. Wastewater facilities treat sewage sludge and stabilize it, reducing odors, pathogen content, and vector attraction potential (making sludge less smelly, free of worms, bacteria, and viruses, and less attractive to rats and flies). Biological processes, chemical processes, and physical processes all can be used to treat sewage sludge.

Biological

- Anaerobic digestion (without oxygen)
- Aerobic digestion
- Composting

Chemical (pH modification)

- Alkaline stabilization
- Lime treatment

Physical (Torri and Cabrera, 2017)

- Pasteurization
- Thermal hydrolysis
- Thermal drying
- Air/solar drying

III. Land Application – Beneficial Use of Biosolids

Spraying, injecting, or tilling human waste onto land is subject to strict regulation. See "Federal, State, and Local Policies" on page 8.

According to the U.S. Environmental Protection Agency, biosolids are "nutrient-rich organic materials resulting from the treatment of domestic sewage in a treatment facility. When treated and processed, these residuals can be recycled and applied as fertilizer to improve and maintain productive soils and stimulate plant growth."

Depending on the level of treatment, the products can be applied to agricultural fields or private lawns and gardens. Private citizens and local communities have expressed some concern over the land-application of biosolids in their area because of the possible hazards of a material produced from human waste. Overall, land application has the potential to minimize environmental and human health impacts that are associated with other methods of disposal, such as landfill.

Grading Biosolids

EQ (Exceptional Quality) and Class B biosolids can be applied to land. Both categories are treated to reduce the amount of bacteria and viruses, odors, and their attraction to pests such as flies and rats. EQ biosolids (formerly called Class A) can be sold in garden centers for household use. https://www.epa.gov/sites/production/files/documents/handbook1.pdf.

The methods by which biosolids are applied to land must be based on the type of land of the application site and the consistency of the biosolids. If not applied properly, biosolids could result in contamination of the surrounding environment, and different land application processes could result in less or more contamination than others.

Biosolids may be liquid or slurry, de-watered, or dried.

Biosolids in liquid or slurry form can be 94 to 97 percent water. In this consistency biosolids can be injected, applied to the surface, or sprayed. Injection of biosolids is accomplished with tankers and hose attachments. Biosolids are pumped from the storage tank to the injection nozzles and released below the surface of the land. When biosolids are applied directly to the surface of the land, they are then usually incorporated (tilled or cultivated) into the soil using farm equipment. Biosolids can also be sprayed. This type of aerosol application is typically seen when biosolids are used for forestry or land reclamation site projects (Biosolids Technology Fact Sheet: Land Application of Biosolids, 2000). Other stormwater best management practices can also be effective.

De-watered biosolids have about 30 percent water, like the consistency of damp soil. This form is applied to land with conventional agriculture equipment. This does not require any special equipment (Biosolids Technology Fact Sheet: Land Application of Biosolids, 2000).

Cake and dried biosolids can be applied via conventional manure spreaders, ag/lime spreaders or fertilizer spreaders.

IV. Benefits of Biosolid Application

There are environmental, economic, and agricultural benefits when biosolids are applied to land safely. Land treated with biosolids generates more crop growth. A growing crop decreases soil erosion and stabilizes contaminants found in the application site, which could otherwise run off into local waterways, polluting them. Biosolid composts can be used in berms and other stormwater management systems (BIOSOLIDS: Frequently Asked Questions, 2014). Another environmental benefit of biosolid application to fields is the reduction of greenhouse gas emission. If biosolids are not put to beneficial use but are placed in landfills, they add to the amount of methane that a landfill produces and eventually releases into the atmosphere (Biosolids: Beneficial Reuse Fact Sheet, 2015). Along with reduction of emissions, biosolid application keeps volume out of landfills and extends the landfill's useful life.

Other Beneficial Use of Biosolids

Research is ongoing on the generation and use of bio-gas, a product of anaerobic digestion. Bio-gas can be combusted to generate electricity and heat, or can be processed into renewable natural gas and transportation fuels. This power source costs more to manufacture than power from fossil fuels but it uses less carbon and so is less harmful to the environment. *(Biosolids Resources – resource recovery and recycling library, 2016).*

In addition to environmental benefits, biosolid application to land has some economic benefits. Local governments can benefit economically from the sale of biosolids to private or public organizations. Selling biosolids generates a profit and eliminates the costs of transportation and dumping into landfills. Trucking sludge and waste is expensive and greatly increases cost to a community. Benefits of the application can provide economic value to end users as well. With biosolid application comes soil improvement, which can in turn build healthier soils and increase or restore farm field productivity. It can provide essential nutrients that crops need to grow, lowering the amount of fertilizer purchased and used (Biosolids Resources – resource recovery and recycling library, 2016).

Lastly, there are many direct agricultural benefits resulting from land application of biosolids. Biosolid application can return key nutrients to fields so there is less or no need to rely on chemical fertilizers. Biosolids increase nutrient retention and cycling of carbon, nitrogen, and phosphorus (Biosolids Resources – resource recovery and recycling library, 2016). In addition to nutrient benefits, soils treated with biosolids can store more carbon. This is possible because carbon found in biosolids will stay within the soil for long periods of time. Plants growing in treated soils grow faster and larger, which in turn pulls more carbon from the atmosphere. This can also help offset emissions associated with synthetic fertilizer use (Biosolids Resources – resource recovery and recycling library, 2016). Soil structure can also benefit from biosolids application. Some noted benefits include decreased soil erosion, increased water retention, and the added benefits of the addition of organic matter. (Biosolids: Beneficial Reuse Fact Sheet, 2015).

V. Potential Impacts to Human and Ecological Health

By law, biosolid recycling programs including land application are required to follow best management practices (BMPs) to protect human health and water quality. In Ohio, the standards for biosolids application are more stringent than for animal manure and chemical fertilizer applications. Although land application of biosolids can offer significant benefits and are regulated, there are also some adverse effects that have been identified to both human and ecological health.

Many human health effects are still being studied, but nuisance odors associated with biosolids is common. Depending on the class of biosolid, there will be some odors that come with application. Odors are not considered related to air quality, and therefore are not regulated by the Clean Air Act. If deemed an issue, odors can be regulated through state and local ordinances (Biosolids Resources – resource recovery and recycling library, 2016).

Although odors don't have a significant impact on human health, other factors may. Studies are being conducted to examine the correlation between living in proximity to fields with biosolid application and adverse health effects. While these studies are in the early stages and have yet to come to any conclusions, scientists and doctors have completed various human health risk assessments for biosolids. A risk assessment is a tool for recognizing possible consequences, along with the severity and likelihood of these consequences (Jenkins, Armstrong, and Monti, 2007).

There are two main things that need to be studied to assess the risk to human health: pathogens and microconstituents in biosolids. The four different types of human pathogens that can be found in biosolids are: protozoa, helminths (roundworms and tapeworms), bacteria, and viruses. Transmitting pathogens to humans from the biosolids can occur in the air, soil, water, and from vectors (e.g. flies). Although there are few studies with evidence showing any general public health problems relating to biosolids, there have been some documented cases related to the direct application and handling of biosolids. The majority of cases were workers within treatment plants. From a collection of 23 studies, observed health effects documented included toxic exposures, viral, bacterial, and protozoan infections including some respiratory and gastrointestinal problems, and irritation and allergic reactions (Jenkins, Armstrong and Monti, 2007). Workers' exposure to pathogens within biosolids is not considered in the EPA's standards and regulations. Risks still exist for people in contact with biosolids, especially considering any outdated operations, knowledge gaps, and new emerging pathogens. More scientific and health studies should be conducted to ensure safety for workers and the public.

Even though biosolids are treated to meet U.S. EPA standards before they are land applied, trace chemicals and contaminants may still have presence in biosolids. Microconstituents that can be found in biosolids fall into six different categories: pharmaceuticals and personal care products, pesticides/fungicides/herbicides, brominated flame retardants, surfactants, plasticizers, and perfluorochemicals (PFAS). Although these are found in biosolids, they are usually in in very low concentrations. Along with these chemicals, biosolids contain some levels of heavy metals. Researchers think that it would take hundreds to thousands of years of exposure working, living, and playing around application sites to harm human health (Kumar, Hundal, Bastian, and Davis, 2017). There are also regulations that mandate maximum permissible loading rates into the soil to manage contaminants (Torri and Cabrera, 2017).

There have also been concerns about how biosolids can impact plants, soil, and water around the application sites. In a study, soybean plants growing in soils applied with biosolids, showed an uptake of carbamazepine, diphenhydramine, and fluoxetine (pharmaceuticals) and triclosan and triclocarban (personal care products). The personal care products and carbamazepine were shown to concentrate themselves in the root tissues and in some other parts including the beans, which are consumed by people and animals. For the other two pharmaceuticals, diphenhydramine and fluoxetine, it was shown that accumulation was very limited. All compounds were shown to have some degree of uptake into the soybean plants, but the rates varied in type of biosolid application (Wu et al., 2010). As of now there is no certainty of any short or long-term negative effects.

Although there are regulations for biosolid pollutant limits, heavy metal concentrations that fall within the limits can affect the crops that grow within fields treated with biosolids. Using remote sensing, a study was completed to examine the stress on crops from the chemical composition of biosolids applied soil. Copper and Molybdenum were found to have accumulated in the shoots of the soybean crop used for testing. And as an increasing amount of biosolids was applied to the field, the chemical concentrations in the roots of the crops and the soil also significantly increased (Sridhar, Vincent, Roberts and Czajkowski, 2011).

In addition to terrestrial effects, there can also be some negative affects to aquatic environments. Runoff into waterways from biosolid-treated fields can contain nutrients, organic matter, trace chemicals (such as those found in personal care products and pharmaceuticals), and fecal coliform. The amount of runoff depends on the type of soil, intensity and duration of the rain event, and application rate of the biosolids (Biosolids Resources – resource recovery and recycling library, 2016). In other studies, scientists assessed the amount of E. coli present in water samples taken before, during, and after application of biosolids, and it was shown that there were significantly higher numbers post-application (Esseili et al., 2012). The E. coli densities observed suggest that application of biosolids and runoff from precipitation events could harm the water quality (Esseili et al., 2012). Mitigation of this runoff includes various management practices including vegetative buffer strips, slope restrictions, seasonal application restrictions, and biosolid containment restrictions (such as placing storage 33 feet away from waterways). When using liquid biosolids, contaminants of varying types tend to migrate towards shallow groundwater. A way to counteract this is by reducing contaminants in the tile drainage systems by using aeration-based pre-tillage (Lapen, Topp, Gottschall, and Edwards, 2018). Many of the components in biosolids have shown no significant short-term impacts; however, they need to be studied further to assess potential long-term impacts.

VI. Research Needs

Additional research is needed to ensure the efficient, safe reuse of biosolids. Specific topics that are not well-researched include:

- Comparison of biosolids and other methods of nutrient application such as animal manure and commercial fertilizer.
    - Do any have an advantage in terms of nutrient availability?
    - How do the risks to human and ecological health compare between these products?
- Local sources and effects of emerging contaminants such as PFAS.
- Potential human and ecological health impacts of contaminants and pharmaceuticals.
    - Is there evidence of negative health impacts experienced by residents living near Class B biosolid application sites?

- What is the potential for contaminant uptake by common crops in northwest Ohio and southeast Michigan?
- If evidence of contaminant uptake is found, what are the possible risks associated with consumption?

- Are there biosolids management practices/processing techniques that are in development (or yet to be developed) that increase treatment or application efficiency or that can further reduce the probability of environmental and human impacts?

Public Education

Wastewater treatment professionals recommend increased education about the land application of biosolids. The biosolids program in the U.S. is well established and regulated but not well understood. Based on discussions with local entities, professionals recommend expanded efforts to communicate with and educate leaders and residents at the local level. Many of the concerns expressed by communities can be addressed by referencing existing regulations and research; it would be beneficial to provide nearby landowners and local officials with access to this information prior to application. Public information sessions should be held, especially in locations where land application is common. Regulators, professionals, researchers, and local governments should collaborate in these efforts. Intensified outreach efforts would also allow a more diverse group of stakeholders to offer input on educational resources and support that local communities can use.

VII. Federal, State, and Local Regulations and Policies

United States Code of Federal Regulations 40, Part 503 establishes federal standards for the preparation, application, and disposal of biosolids. These rules include minimum standards for the concentration of primary pollutants, the treatment of pathogens, and vector attraction reduction (VAR). Based upon these three criteria the rule provides management requirements for types of application, monitoring and recordkeeping, and methods of disposal. Regulations at the state level must, at a minimum, comply with the federal standards.

In Michigan and Ohio, regulations specify treatment practices to minimize pathogen and pollutant levels, application rules, management practices to reduce ecological and human health impacts, and other management considerations for producers or users of biosolids. Ohio Administrative Code 3745-40, *Sewage Sludge* establishes the sewage sludge rules for the State of Ohio. Michigan Part 24 *Biosolids Rules* of Part 31, *Water Resources Protection*, of the *Natural Resources and Environmental Protection Act* (NREPA) establishes the sewage sludge rules for the State of Michigan. Following are some examples of state-level regulations for Michigan and Ohio; for full details please refer to the appropriate documents.

The state of Ohio follows the federal rules for land application, with some additions. For example, Ohio has rules pertaining to surface application when precipitation is forecast, with more stringent cutoffs for certain soil types. Class B biosolids cannot be surface applied to any soil types during precipitation, or if “there is at least a fifty per cent chance that 0.5 inches of rain will occur within twenty-four hours after beneficial use.” In areas with hydrologic soil group D (soils with a high runoff potential due to factors such as high percentage of clay, an impermeable layer less than 20 inches below the surface, or a water table within 24 inches of the surface), the guidance applies with a threshold of 0.25 inches.

Michigan regulations are also more specific or stringent than federal rules in some cases. Like Ohio and federal regulations, Michigan states that biosolids application must be limited by the agronomic rate. Furthermore, the state sets standards for the maximum amount of plant-available nitrogen that can be applied to tree farms and forestland. Michigan is more stringent than both federal and Ohio regulations when it comes to surface application isolation distances for surface waters (50 feet in Michigan versus 33 feet) yet allows application closer to domestic wells and buildings. There are no specific rules in the state of Michigan pertaining to forecasted rainfall or certain soil types, but application may only take place in areas where the water table is a minimum of 30 inches below the surface.

Ohio Revised Code 6111.03 (R)(2) states that the Director of the Ohio EPA "has exclusive authority to regulate sewage sludge management in this state," so that local jurisdictions in Ohio cannot establish policies that conflict in any way with policies established by the Director. According to the Michigan NREPA section 324.3133 (3), local jurisdictions can establish policies "in addition to or more stringent than" rules established by the Michigan Department of Environment, Great Lakes, and Energy if:

(a) The operation of a sewage sludge or sewage sludge derivative land application site within that local unit will result in unreasonable adverse effects on the environment or public health within the local unit. The determination that unreasonable adverse effects on the environment or public health will exist shall take into consideration specific populations whose health may be adversely affected within the local unit.

(b) The operation of a sewage sludge or sewage sludge derivative land application site within that local unit has resulted or will result in the local unit being in violation of other existing state laws or federal laws.

Those who produce or surface apply biosolids must adhere to regulations at the federal, state, and local levels. Permitting and specific rulemaking typically happens at the state level, so review of state regulations and coordination with the appropriate state agency officials are crucial. In Ohio, the Biosolids Program is housed in the Ohio EPA Division of Surface Water. In Michigan, Biosolids & Industrial Pretreatment are a Surface Water Program of the Michigan Department of Environment, Great Lakes, and Energy. Contact information for these agencies is listed in the Appendix.

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Youtube video:

Snyder & Associates, Inc. – Ankeny, IA, "Biosolids Managements: Reports, Regulations, & Land Application", YouTube video, 30:36, August 14, 2019, https://www.youtube.com/watch?v=8FhTeSGdhpQ

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Lapen, D., Topp, E., Gottschall, N., and Edwards, M., 2018. Land Application of Municipal Biosolids: Managing the Fate and Transport of Contaminants of Emerging Concern. *Multidisciplinary Journal for Waste Resources & Residues*, 1, pp.122-127.

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Appendix A: Additional Resources

General/Background Information

1. WEF Biosolids Resources page: http://biosolidsresources.org/OE/
2. WEF Biosolids Technical Documents page (Biosolids > Technical Resources > Technical Documents): https://www.wef.org/resources/topics/browse-topics-a-n/biosolids/
3. EPA Biosolids Technology Fact Sheet – Land Application of Biosolids: https://www3.epa.gov/npdes/pubs/land_application.pdf
4. NEBRA Biosolids Fact Sheet: https://static1.squarespace.com/static/54806478e4b0dc44e1698e88/t/5488744ce4b08cb18eeef826/1418228812325/BiosolidsFAQ-NEBRA2014.pdf

Regulations/Policies

1. National Biosolids Partnership: Recognizing a Resource: Biosolids, Part 1 Federal & State Regulation: https://static1.squarespace.com/static/54806478e4b0dc44e1698e88/t/58cab99f1b10e368df4041ae/1489680818368/NBP-RecognizingAResource-Biosolids-Part1-Jan13-Small.pptx.pdf
2. EPA Biosolids Program and 40 CFR part 503: https://static1.squarespace.com/static/54806478e4b0dc44e1698e88/t/5dd551acedd466018dad715d/1574261166490/USEPA-503Basics-Biosolids%26EPATeam%26503-BiosolidsWebinarSeries%231-23Oct2019.pdf
3. EPA 40CFR part 503 Regulations, Biosolids 101: Pathogen and Vector Attraction Reduction Regulations: https://static1.squarespace.com/static/54806478e4b0dc44e1698e88/t/5dd5525128b12a6e57a87b50/1574261332251/USEPA-503Basics-Pathogens%26VAR-BiosolidsWebinarSeries%232-13Nov2019.pdf
4. EPA Biosolids Laws and Regulations: https://www.epa.gov/biosolids/biosolids-laws-and-regulations
5. Ohio EPA Division of Surface Water Biosolids: https://www.epa.ohio.gov/dsw/sludge/biosolid | Contact: 614.644.2150
6. Michigan Department of Environment, Great Lakes, and Energy: https://www.michigan.gov/egle/0,9429,7-135-3313_71618_3682_3683_3720---,00.html | Contact: 989.297.0779

Public/Private Implementation

1. High Performance Anaerobic Digestion: https://www.wef.org/globalassets/assets-wef/3---resources/topics/a-n/biosolids/technical-resources/high-performance-ad-final.pdf
2. Snyder & Associates Presentation on Biosolids Management: https://www.youtube.com/watch?v=8FhTeSGdhpQ

Potential Benefits of Land Application

1. Vermont Agency of Natural Resources – Biosolids Beneficial Reuse Fact Sheet: https://static1.squarespace.com/static/54806478e4b0dc44e1698e88/t/5852d7a7f5e231640d1e8c7b/1481824168549/VT-BiosolidsBeneficialReUseFactSheet2015.pdf

2. WEF Podcast – Words on Water: #37 Ned Beecher on the Benefits of Biosolids: https://wordsonwaterwef.com/2018/06/11/words-on-water-37-ned-beecher-on-the-benefits-of-biosolids/
3. WEF Podcast – Words on Water: #45 Manon Fisher on Addressing Climate Change with Biosolids: https://wordsonwaterwef.com/2018/08/01/words-on-water-45-manon-fisher-on-addressing-climate-change-with-biosolids/
4. Biosolids Safe for Land Application: https://uanews.arizona.edu/story/biosolids-safe-land-application-ua-researchers-find

Potential Impacts of Land Application

1. Human Health Risk Assessment Related to Microconstituents: https://www.wef.org/globalassets/assets-wef/3---resources/topics/a-n/biosolids/technical-resources/wef-fact-sheet-microconstituents-v25-aug-2017.pdf
2. Phosphorus in Biosolids: How to Protect Water Quality While Advancing Biosolids Use: https://www.wef.org/globalassets/assets-wef/3---resources/topics/a-n/biosolids/technical-resources/1-page-p-fact-sheet-v25-jul-2016.pdf
3. The Environmental Impact of Biosolids' Land Application: https://www.researchgate.net/profile/Musa_Bishir2/publication/317771558_Biogas_production_from_organic_waste_Focus_on_microbial_methanogenesis/links/5cd03d3ea6fdccc9dd906ad3/Biogas-production-from-organic-waste-Focus-on-microbial-methanogenesis.pdf#page=199
4. Land Application of Municipal Biosolids: Managing the Fate and Transport of Contaminants of Emerging Concern: https://digital.detritusjournal.com/articles/land-application-of-municipal-biosolids-managing-the-fate-and-transport-of-contaminants-of-emerging-concern-/31
5. Biosolids and Bioaerosols: http://faculty.washington.edu/slb/docs/basics/bioaerosolsNB.pdf
6. Metals in Biosolids: http://faculty.washington.edu/slb/docs/basics/Metals_in_biosolids.pdf
7. Health Effects of Biosolids Applied to Land: Available Scientific Evidence https://www.dphu.org/uploads/attachements/books/books_4453_0.pdf
8. Land Application of Biosolids: Human Health Risk Assessment Related to Microconstituents: https://www.wef.org/globalassets/assets-wef/3---resources/topics/a-n/biosolids/technical-resources/wef-fact-sheet-microconstituents-v25-aug-2017.pdf
9. Household Chemicals and Drugs Found in Biosolids from Wastewater Treatment Plants: https://toxics.usgs.gov/highlights/biosolids.html