Pathogens and Biosolids

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Pathogens are disease-causing microorganisms that include bacteria, viruses, protozoa, and helminths (parasitic worms). Pathogens can present a public health hazard if they are transferred to food crops grown on land to which biosolids are applied; contained in runoff to surface waters or in leachate to groundwater from land application sites; or transported away from the site by vectors such as insects, rodents, and birds. For this reason, federal and state regulations specify pathogen and vector attraction reduction requirements that must be met by biosolids applied to land. Lists of pathogens that can be found in untreated sewage sludge and the diseases or symptoms that they can cause have been extensively documented (U.S. EPA, 1995; U.S. EPA, 2003; Compost Science & Utilization, 2005; Sidhu and Toze. 2009).

In 1993, the U.S. EPA implemented regulations entitled "The Standards for the Use or Disposal of Sewage Sludge" (U.S. EPA, 1993). These regulations, promulgated as 40 CFR (Title 40, Code of Federal Regulations), Part 503 Biosolids Rule (Part 503 Rule), were established to protect public health and the environment from adverse effects of pollutants and pathogens in biosolids.

The 503 Rule specifies minimum federal regulations for pathogen and vector attraction reduction requirements that must be met by biosolids applied to land. Currently, the only pathogens regulated are fecal coliform, Salmonella spp., enteric viruses, and helminths. This group of pathogens are known as indicator microorganisms, as they can indicate the presence of a larger set of pathogens. Listed below is the rationale for each microorganism's regulation (US EPA, 2003).

- Fecal coliforms are directly proportional to fecal wastes, present in high numbers, and easier to quantify than other pathogens.
- Salmonella spp., especially S. enteritidis (the single most common cause of food poisoning in the U.S.) are so widespread that they typically exist in untreated sewage sludge. Due to their large numbers, it can be assumed that effective disinfection has occurred if Salmonella spp. are at or below the detection limit.
- Enteric viruses were chosen as they are shed in large numbers by infected individuals and inherently resistant to environmental stresses, including heat and low pH. If conditions are effective for disinfection of enteric viruses, they are most likely effective for most other viruses and bacteria.
- When assessing parasitic worms, Ascaris (genus of parasitic nematode worms, e.g. small intestinal roundworms) ova are the organism of choice. This is due to their thick shells which are highly resistant to stressors, especially commonly used disinfection chemical stressors. However, the absence of helminth ova is no longer an acceptable indicator of adequate pathogen reduction in the U.S. Cleaner water supplies and better personal hygiene practices have steadily decreased helminth infections, reducing numbers present before biosolids treatment.

Virginia Biosolids Council

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Categories of Biosolids Quality with regard to Pathogens

There are two classes of pathogen reduction for biosolids that can be applied to land: Class A and Class B. Class A requires treatment processes to further reduce pathogens (PFRPs) and Class B requires treatment processes to significantly reduce pathogens (PSRPs) (U.S. EPA, 2003). Treatment processes to achieve these Class designations are described in the fact sheet entitled "Wastewater Treatment Processes" (Alvarez-Campos and Evanylo). The following describes the standards for and acceptable use of biosolids treated to Class A and B.

Class A pathogen reduction is necessary if biosolids are to be applied to lawns, home gardens, or other land having high public access, or bagged for land application. Public access is not restricted for biosolids applied to land that meet Class A standards. To meet regulations for land application, Class A biosolids' pathogen densities must meet the following:

- $<$ 3 most-probable-number (MPN) per 4 grams total solids biosolids (dry weight basis) for density of Salmonella sp.;
- $<$ 1 plaque-forming-unit (PFU) per 4 grams total solids biosolids (dry weight basis) for enteric viruses; and
- $<$ 1 viable helminth ova per 4 grams total solids biosolids (dry weight basis) for viable helminth ova.

Class B biosolids can be applied to land, but site restrictions that limit crop harvesting, animal grazing, and public access for a specified period of time are required. Reduction of pathogen densities to those of Class A are expected to occur via exposure to inhospitable temperature, moisture, and light conditions and microbial antagonisms during such periods. To meet regulations for land application, Class B pathogen reduction must meet the following:

- A fecal coliform density in the treated biosolids of 2 million MPN or colony forming unit (CFU) per gram total solids biosolids (dry weight basis). As a note, viable helminth ova are not necessarily reduced in Class B biosolids.

Vectors

There are two classes of pathogen reduction for biosolids that can be applied to land: Class A and Class B. Class A requires treatment processes to further reduce pathogens (PFRPs) and Class B requires treatment processes to significantly reduce pathogens (PSRPs) (U.S. EPA, 2003). Treatment processes to achieve these Class designations are described in the fact sheet entitled "Wastewater Treatment Processes" (Alvarez-Campos and Evanylo). The following describes the standards for and acceptable use of biosolids treated to Class A and B.

As vectors (e.g., rodents, birds, insects) can spread diseases by harboring and transferring pathogens, reducing the attractiveness of biosolids to vectors reduces the potential for transmitting diseases from pathogens in biosolids. There are no published reports that implicate the transmission of infectious organisms from land-applied biosolids to humans. Part 503 regulation contains 12 options for demonstrating a reduction in vector attraction of sewage sludge (U.S. EPA, 2003).

Fate of Pathogens in the Environment

Extensive research has been performed to assess the fate of pathogens in land-applied biosolids. Pathogen die more rapidly in hot, dry than moist, cold soils (Sagik and Sober, 1978). Bacteria usually die off within a few weeks, while viruses may survive for months, and encysted parasites may survive for up to 10 years (Angle, 1994). Pathogenic microorganisms, due to their small size, may leach through soil pores into groundwater, with viruses leaching the furthest (Gerba et al., 1975). Microorganisms are transported most rapidly through coarse-textured soils and under saturated flow (Angle, 1994). Despite the potential for survival in and transport through soils of biosolids-borne pathogenic microorganisms, there has been little evidence of health hazards from land-applied biosolids (Angle, 1994).

Repeated reviews of land application programs concluded that there have been no reported outbreaks of infectious disease associated with human exposure – either directly or through food consumption pathways – to adequately-treated and properly distributed biosolids applied to agricultural land (National Research Council, 1996; National Research Council, 2002). A review of occurrence of clinical disease associated with occupational exposure among wastewater treatment plant operators and maintenance personnel indicated rare reporting of infection (Cooper, 1991); thus, it is not unreasonable that agricultural workers exposed to biosolids would face an even lower risk of infectious disease. The potential detrimental effects of aerosols generated by wastewater treatment plants on the surrounding community has also been studied with no health effects demonstrated (Pharen, 1979). More recently, Brooks et al. (2004) demonstrated that risks of pathogen infection of the general population from aerosols generated during a variety of biosolids spreading methods are negligible.

In recent years, emerging organisms (e.g., Escherichia coli 0157:H7, Staphylococcus aureus) and prions (proteinaceous infectious particle responsible for such neurodegenerative diseases as bovine spongiform encephalopathy, or BSE) have elicited concern due to potential infection (National Research Council, 2002). Despite possible modes of transmission, there have been no associations between land application of biosolids and reported infection by such biosolids constituents. A study by Yates and Yates (2007) demonstrated variable, but minor, survival and transport through soil columns that mirrored field results. The greatest risk of microbial pathogen transport occurs in coarser-textured and more highly saturated soils. A comprehensive state-of-the-science workshop on infectious disease agents in sewage sludge and manure held in 2001 resulted in a publication (Compost Science & Utilization, 2005) that documented the most recent knowledge on pathogen (including emerging issues) survival, fate, and infection risk and research needs.

Another recent issue of increasing concern with regard to microbial pathogens is whether additional sources of antibiotic resistant genes (ARG) in land-applied biosolids contribute to antibiotic resistance levels in the environment. A recently published research review by Pepper et al. (2018) indicates that “while antibiotic resistance levels in soil are increased temporally by land application of wastes, their persistence is not guaranteed and is in fact variable, and often contradictory based on application site. Furthermore, the application of wastes may not produce the most direct impact of ARGs and ARB [antibiotic resistant bacteria] on public health. Further investigation is still warranted in agriculture and public health, including continued scrutiny of antibiotic use in both sectors.”

Concerns over potential risks from pathogens associated with land application of biological wastes will likely continue. Increasing adoption of PFRP treatment methods and development of a microbial risk assessment to quantify such risks will allay such concerns. Such a microbial risk assessment tool, the SMART Biosolids Tool, was developed by a team of researchers via a WERF-funded project entitled “Site Specific Risk Assessment Tools for Land-Applied Biosolids” (Gurian et al., 2012). Field monitoring studies to validate model results measured no detectable quantities of pathogens after transport through several feet of soil; however, trace amounts of pathogens and indicators were detected from surface runoff. The risk assessment model quantified microbial risk due to contamination of surface waters from land application runoff to be more than a factor of 10 below existing risk standards for recreation surface waters.

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