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Agricultural Land Application of Biosolids in Virginia: Risks and Concerns

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Introduction

The benefits of recycling biosolids onto agricultural land include providing essential nutrients for crop needs and organic matter for improving soil tilth, water-holding capacity, soil aeration, and an energy source for earthworms and beneficial microorganisms. Crop yields on land amended with biosolids can be as great or greater than land fertilized with only commercial synthetic fertilizers. Notwithstanding these agricultural benefits, the use of biosolids is not without some disadvantages and risks. This publication summarizes the current understanding of those concerns.

Disadvantages of land application

Large land areas may be needed for agricultural use of biosolids because application rates are relatively low. Transportation and application scheduling that is compatible with agricultural planting, harvesting, and possible adverse weather conditions require careful management.

Biosolids, even when properly treated, will have odors. Under unfavorable weather conditions, the odors may be objectionable, even to rural communities accustomed to the use of animal manure. Odors may be reduced by stabilization process, application method, storage type, climatological conditions, and site selection as described below.

Stabilization reduces the biological activity and odor of biosolids. The products of aerobic digestion, heat treatment, and composting tend to result in the least objectionable odors. Anaerobic digestion has the potential to cause more odor than other treatment methods if not performed properly. Likewise, lime-stabilized biosolids, the most commonly used material in the state, may generate odors if not properly stabilized and managed.

Application method affects the odor potential at the site. Immediate soil incorporation or direct soil injection reduce the potential for odor problems.

Biosolids storage can occur at the treatment plant, the site of application, or a temporary facility. Storage at the treatment plant (if isolated from the public) is the preferred method. Off-site storage requires proper site selection and management to minimize the potential for odor problems.

Weather conditions (i.e., temperature, relative humidity, wind) will affect odor severity when biosolids are surface-applied. Spreading in the morning when air is warming and rising will help dilute the odor in the immediate vicinity.

The selection of the application site is important to the success of the operation. The site should ideally be located away from residential areas. Objectionable odors will sometimes be present despite adequate stabilization processes and favorable weather conditions. Complaints can be expected if adjacent property

Dewatered biosolids being delivered to an application site.

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owners are subjected to persistent odors. A well-managed system with the proper equipment and stabilized biosolid will substantially reduce the potential for unacceptable odors.

Biosolids are typically delivered to the application site by tractor trailers that haul approximately 20 tons. At a solids content of 15-25 percent, this is approximately 3-5 dry tons per trailer, or about the amount of biosolids that is normally spread onto one acre of land for crops such as corn, soybean or wheat. Therefore, there will be considerable truck volume over the course of several weeks for large sites of several hundred acres. Increased traffic on local roads, odors and dust are potential impacts on the local community that should be addressed by notifying neighbors in public informational meetings or public hearings. Working out delivery schedules that are least likely to be disruptive will minimize the problems caused by biosolids transportation.

Human health and environmental risks

Risk assessment approach to regulation

Quality standards and limits for pollutants in biosolids were developed from extensive environmental risk assessments conducted by scientists at the U.S. EPA and the U.S. Department of Agriculture. EPA used a rigorously reviewed methodology that they developed specifically for conducting the assessment (National Academy of Sciences, 1983; U.S. EPA, 1986). The goal of the risk assessment was to protect a person, animal or plant that is highly and continuously exposed to pollutants in biosolids. The rationale for this goal is that the general population would be protected if the regulations were developed to protect highly exposed individuals.

The risk assessment process was the most comprehensive analysis of its kind ever undertaken by the EPA. The approach has since been applied to other materials, such as municipal solid waste compost. The resultant Part 503 Rule was designed to provide "reasonable worst-case," not absolute, protection to human health and the environment.

Part 503 risk assessment

The initial task of the 10-year risk assessment process was to establish a range of concentrations for trace elements and organic compounds that had the greatest potential for harm based on known human, animal and plant toxicities. Maximum safe accumulations for the chemical constituents in soil were established from the most limiting of 14 pathways of exposure (Table 1), which included risks posed to human health, plant toxicity and uptake, effects on livestock or wildlife, and water quality impacts. A total of 200 chemical constituents were screened by EPA, and 50 of these were selected for further evaluation, using the criteria above and the availability of data for a preliminary risk assessment. Twenty-three of the 50 constituents were identified as warranting consideration for regulation based on the risk assessment. No regulatory limits were set for the 13 trace organic compounds in this group because the EPA risk assessment showed that the safe levels were considerably higher than the observed concentrations in biosolids. The 503 rule was then limited to ten trace elements (arsenic, cadmium, chromium, copper, lead mercury, molybdenum, nickel, selenium, and zinc). Chromium was subsequently dropped on a court challenge because the risk assessment had shown a very low risk level for this metal.

The most limiting pathway for each of the nine regulated trace elements was used to develop pollutant concentration limits and lifetime loading rate standards. For example, the greatest risk to a target organism from lead (Pb) is a child directly ingesting biosolids that have been applied to soil. The pollutant limits are therefore based on estimates of childhood soil consumption that EPA considered conservative (i.e., they predict a greater impact on human health than is likely to occur). Ingestion of biosolids is the most limiting pathway for five of the trace elements (As, Cd, Pb, Hg, and Se), phytotoxicity was most limiting for three trace elements (Cu, Ni, and Zn), and feed consumption by animal was the most limiting for Mo.

Under Part 503, the cumulative loading limits established by EPA for eight trace elements would allow the concentrations of these elements to increase to levels that are 10 to 100 times the normal background concentrations in soil (Table 2). The time that it would take for each of the eight elements to reach its cumulative loading limit when biosolids with typical trace element concentrations (Evanylo, 1999b -Table 1; U.S. EPA, 1990) are applied annually at a rate of 5 dry tons per acre is presented in Table 2. These are conservative estimates for Virginia, where agronomic loading rates are normally applied once every three years, not annually. The cumulative loading limits were developed to ensure that soil metals never reach harmful levels. Future applications of biosolids to the site would be prohibited if the cumulative loading limit for any of the eight trace elements was reached.

Table 1

Exposure Pathways Used in the Part 503 Risk Assessment.

Pathway	Description of Highly Exposed Individual
1. Sludge→Soil→Plant→Human	Human (except home gardener) lifetime ingestion of plants grown in sludge-amended soil
2. Sludge→Soil→Plant→Human	Human (home gardener) lifetime ingestion of plants grown in sludge-amended soil
3. Sludge→Human	Human (child) ingesting sludge
4. Sludge→Soil→Plant→Animal→Human	Human lifetime ingestion of animal products (animals raised on forage grown on sludge-amended soil)
5. Sludge→Soil→Animal→Human	Human lifetime ingestion of animal products (animals ingest sludge directly)
6. Sludge→Soil→Plant→Animal	Animal lifetime ingestion of plants grown on sludge-amended soil
7. Sludge→Soil→Animal	Animal lifetime ingestion of sludge
8. Sludge→Soil→Plant	Plant toxicity due to taking up sludge pollutants when grown in sludge-amended soils
9. Sludge→Soil→Organism	Soil organism ingesting sludge-soil mixture
10. Sludge→Soil→Predator	Predator of soil organisms that have been exposed to sludge-amended soils
11. Sludge→Soil→Airborne dust→Human	Adult human lifetime inhalation of particles (dust) [e.g., tractor driver tilling a field]
12. Sludge→Soil→Surface water→Human	Human lifetime drinking surface water and ingesting fish containing pollutants in sludge
13. Sludge→Soil→Air→Human	Human lifetime inhalation of pollutants in sludge that volatilize to air
14. Sludge→Soil→Groundwater→Human	Human lifetime drinking well water containing pollutants from sludge that leach from soil to groundwater

Table 2

Possible trace element concentrations in typical unamended and biosolids-amended soils, and the time required to reach cumulative loading limits for the regulated trace elements.

Trace element	Typical background soil concentration range for non-contaminated[a] ppm	Theoretical soil concentration at EPA cumulative loading limit[b] ppm	Time required to reach cumulative loading limit[c] years
Arsenic	6-10	21	360
Cadmium	0.2-0.5	20	500
Copper	17-65	750	181
Lead	8-22	150	201
Mercury	0.06-0.15	9	320
Nickel	7-45	210	871
Selenium	0.3-0.4	50	1780
Zinc	19-82	1,400	208

[a] Penn State University, 1998

[b] Theoretical maximum soil concentrations after application of the maximum allowable amount of that element.

[c] Assumes an annual application rate of 5 dry tons/acre of a biosolid with trace element concentrations equal to the means in Table 3.1

Alternative regulatory approaches

Best available technology

An alternative to the risk assessment approach, termed "best available technology" or BAT, limits contaminants in biosolids to concentrations attained by the best current technology (e.g., industrial pre-treatment and separation of sanitary, storm and industrial sewerage). BAT is more restrictive of land application than risk assessment (i.e., lower pollutant concentrations can be attained using the best available technology than are permitted under the risk assessment approach). Biosolids are more likely to be landfilled or incinerated under this approach than under risk assessment.

Non-contamination approach

The EPA Part 503 regulations take the position that all biosolids management options incur some risk, and that these risks can be evaluated so that regulations governing use and management options can be developed to reduce risk to acceptable (safe) levels. There are some who believe that the application of any biosolid that would cause an increase in the soil concentration of any pollutant is unacceptable. This is called the "non-contamination" approach. According to this approach, any addition of a pollutant to the soil must be matched by removal of that pollutant so that no long-term buildup occurs in the soil. This is the most restrictive of approaches to the land application of biosolids and is favored by those who believe that any increase in pollutant concentration in the soil is undesirable, regardless of what risk assessment demonstrates. Although this approach reduces to zero any environmental risks from land application of biosolids, it diverts more biosolids to landfills or incinerators, thereby increasing the environmental risks associated with disposal and reduces recycling of nutrients and organic matter.

Each approach for regulating contaminants in biosolids has its technical and scientific foundation, but the approach selected is based primarily on legislative mandates and policy decisions.

Pathogen regulation

Standards for pathogen reduction in biosolids were based on "best available technology." The EPA believes that the potential for pathogen transfer is negligible when biosolids are properly processed and the regulatory requirements for land application are met (U.S. EPA, 1987). The 503 rule establishes two levels of pathogen destruction - Class B, in which about 99% of the bacteria, 90% of the viruses, and a lower percentage of the more resistant parasites are killed; and Class A, where essentially 100% of all pathogens are destroyed. Protection against residual pathogens in Class B biosolids is achieved through crop harvesting restrictions, grazing restrictions, and public access restrictions based on the understanding that, given enough time, the residual pathogens in Class B biosolids are destroyed in the soil. Exposure to sunlight and temperature and moisture fluctuations in the soil reduces and eventually eliminates any viable pathogens that may remain in the biosolids (U.S. EPA, 1992c).

Class B standards are 2000 times less stringent than Class A; thus, compliance with the management practice restrictions is critical for protection of the public health and the environment. A positive trend relative to pathogen risk is that many Class B treatment processes are achieving near Class A pathogen levels. The trend was only identified because 503 for the first time requires pathogen testing for compliance. Another positive trend observed in recent years is the rapid increase in production of Class A biosolids, whose application to land poses essentially zero risk of pathogen transfer.

Can biosolids be used safely?

Despite the endorsement of agricultural land application of biosolids by the U.S. EPA and a considerable number of agricultural and environmental scientists (National Research Council, 1996; American Society of Agronomy, 1994; Stukenberg et al., 1993), some scientists dispute the claim that biosolids used according to EPA guidelines can be safely applied in all instances. These scientists cite concerns about the buildup of toxic concentrations of trace elements in the soil and the food chain; the potential transport of pathogens into water, air and the human food chain; the potential toxicity and carcinogenicity of the multitude of organic compounds; and risk from other constituents which have not been thoroughly studied (e.g., radioactive isotopes). Standards and practices more conservative than required by the Part 503 Rule have been developed and recommended by the Technical Committee of Northeastern Regional Research Coordinating Project (NEC-28, Soil Research) [Pennsylvania State University, 1985] and the Cornell Waste Management Institute (Harrison et al., 1997). The NEC-28 recommendations contain much "best professional judgement," and call for reevaluation of the recommendations as research generates new knowledge.

Future Directions

A second round of risk assessments will be conducted by the EPA. Several trace elements and organic chemicals that were not considered extensively during the initial risk assessments will be evaluated, and will include the results of numerous scientific studies completed since 1993. These activities will probably result in some changes of the current regulations. These changes could include (1) adding some organic chemicals (i.e., dioxins and co-planar PCBs) to the list of regulated pollutants and (2) adding a cumulative loading rate for molybdenum.

Conclusions

Based on more than 25 years of research on land application of biosolids and an even longer record of beneficial use in the United States, the preponderance of scientific evidence indicates that land applying biosolids of the quality currently generated according to the regulations established by the U.S. EPA and the Commonwealth of Virginia will not result in significant detrimental health or environmental impacts. On-going research and evaluation of regulatory programs should continue until lingering arguments and concerns are satisfactorily addressed, or the questions raised will continue to create doubt among the public. Site specific assessment of the practice should take into account the potential for a specific biosolid to deviate greatly from the norm.

Further information can be found in the following Virginia Cooperative Extension fact sheets on agricultural land application of biosolids in Virginia: VCE Publication 452-301, Production and characteristics (Evanylo, 1999b); VCE Publication 452-302, Regulations (Evanylo, 1999c), and VCE Publication 452-303, Managing biosolids for agricultural use (Evanylo, 1999d).

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