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AGRICULTURAL LAND APPLICATION OF BIOSOLIDS IN VIRGINIA: PRODUCTION AND CHARACTERISTICS OF BIOSOLIDS

*G.K. EVANYLO**

What are biosolids and how are they different from sewage sludge?

Biosolids are solid, semi-solid or liquid materials, resulting from treatment of domestic sewage, that have been sufficiently processed to permit these materials to be safely land-applied. The term was introduced by the wastewater treatment industry in the early 1990's and has been recently adopted by the United States Environmental Protection Agency (U.S. EPA) to distinguish high quality, treated sewage sludge from raw sewage sludge and from sewage sludge containing large amounts of pollutants. Some groups have charged that the term "biosolids" has been employed to disguise the real nature of sewage sludge from the general public, thereby reducing objections to land application of sewage sludge. Although "biosolids" does not evoke the same negative connotation as does "sewage sludge," the use of the term is appropriate when it makes the distinction described above.

How are biosolids produced?

Biosolids are produced primarily through biological treatment of domestic wastewater. Biosolids comprise the solids that are removed from the wastewater and further processed before the treated water is released

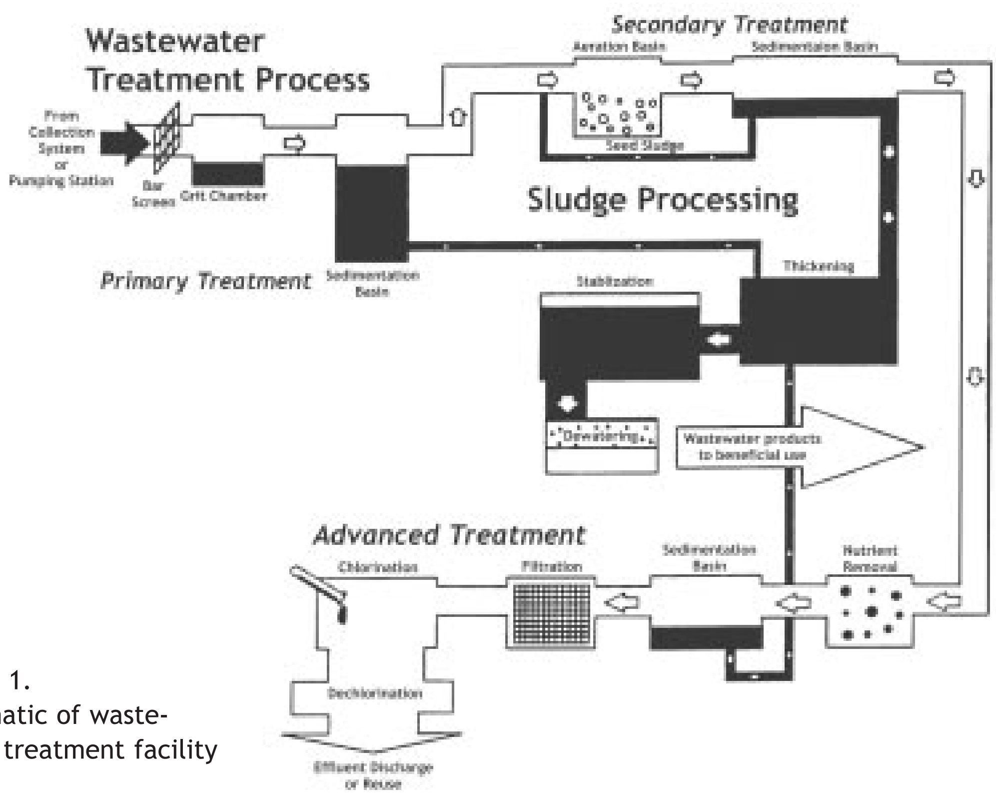

Figure 1. Schematic of wastewater treatment facility

*Extension Specialist, Department of Crop and Soil Environmental Sciences,Virginia Tech

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into streams or rivers (Fig. 1). Physical and chemical processes are often employed additionally to improve the biosolids handling characteristics, increase the economic viability of land application, and reduce the potential for public health, environmental and nuisance problems associated with land application practices. These processes sanitize wastewater treatment solids to control disease-causing organisms and reduce characteristics that might attract rodents, flies, mosquitoes, or other organisms capable of transporting infectious disease. The type and extent of processes used to treat wastewater will affect the degree of pathogen reduction attained and the potential for odor generation. Common treatment processes and their effects on biosolids properties and land application practices are summarized in Table 1.

Table 1
Effects of biosolids treatment processes on land application practices (Adapted from U.S. EPA, 1984).

Treatment Process and Definition	Effect on Biosolids	Effect on Land Application Practices
Thickening: Low force separation of water and solids by gravity, flotation, or centrifugation.	Increases solids content by removing water.	Lowers transportation costs.
Digestion (anaerobic and aerobic): Biological stabilization through conversion of organic matter to carbon dioxide, water, and methane.	Reduces the biodegradable content (stabilization) by conversion to soluble material and gas. Reduces pathogen levels and odor.	Reduces the quantity of biosolids.
Alkaline stabilization: Stabilization through the addition of alkaline materials (e.g., lime, kiln dust).	Raises pH. Temporarily decreases biological activity. Reduces pathogen levels and controls putrescibility and odor.	High pH immobilizes metals as long as pH levels are maintained.
Conditioning: Processes that cause biosolids to coagulate to aid in the separation of water.	Improves sludge dewatering characteristics. May increase dry solids mass and improve stabilization.	The ease of spreading may be reduced by treating biosolids with polymers.
Dewatering: High force separation of water and solids. Methods include vacuum filters, centrifuges, filter and belt presses, etc.	Increases solids concentration to 15% to 45%. Lowers nitrogen and potassium concentrations. Improves ease of handling.	Reduces land requirements and lowers transportation costs.
Composting: Aerobic, thermophilic, biological stabilization in a windrow, aerated static pile or vessel.	Lowers biological activity, destroys pathogens, and converts sludge to humus-like material.	Excellent soil conditioning properties. Contains less plant available nitrogen than other biosolids.
Heat drying: Use of heat to kill pathogens and eliminate most of the water content.	Disinfects sludge, destroys most pathogens, and lowers odor and biological activity.	Greatly reduces sludge volume.

Characterization of biosolids

The suitability of a biosolid for land application can be determined by biological, chemical, and physical analyses. Biosolids' composition depends on wastewater constituents and treatment processes. The resulting properties will determine application method and rate, and the degree of regulatory control required. Several of the more important properties of biosolids are discussed below.

Total solids (TS) include suspended and dissolved solids and are usually expressed as the concentration present in biosolids. TS depend on the type of wastewater process and biosolids' treatment prior to land application. Typical solids contents of various biosolids' processes are: liquid (2-12%), dewatered (12-30%), and dried or composted (50%).

Volatile solids (VS) provide an estimate of the readily decomposable organic matter in biosolids and are usually expressed as a percentage of total solids. VS are an important determinant of potential odor problems at land application sites. A number of treatment processes, including anaerobic digestion, aerobic digestion, alkaline stabilization, and composting, can be used to reduce VS content and, thus, the potential for odor.

pH is a measure of the degree of acidity or alkalinity of a substance. The pH of biosolids is often raised with alkaline materials to reduce pathogen content and attraction of disease-spreading organisms (vectors). High pH (greater than 11) kills virtually all pathogens and reduces the solubility, biological availability and mobility of most metals. Lime also increases the gaseous loss (volatilization) of the ammonia (NH_3) form of nitrogen (N), thus reducing the N-fertilizer value of biosolids.

Pathogens are disease-causing microorganisms that include bacteria, viruses, protozoa, and 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 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. A partial list of pathogens that can be found in untreated sewage sludge and the diseases or symptoms that they can cause are presented in Table 2.

Table 2

A partial list of pathogens that can be found in municipal wastewater and solids and diseases or symptoms they cause (adapted from U.S. EPA, 1995).

Organism	Disease/Symptoms
Bacteria	
Salmonella sp.	Salmonellosis (food poisoning), Typhoid fever
Escherichia coli	Gastroenteritis
Shigella sp.	Bacillary dysentery, severe gastroenteritis
Enteric Viruses	
Hepatitis A virus	Infectious hepatitis
Echoviruses	Meningitis, paralysis, encephalitis, fever, “flu-like” symptoms, diarrhea, etc.
Protozoa	
Entamoeba histolytica	Amoebic dysentery
Giardia lamblia	Diarrhea, abdominal cramps, weight loss
Helminth Worms	
Ascaris sp.	Digestive and nutritional disturbances, abdominal pain, vomiting, restlessness, coughing, chest pain, and fever
Trichuris trichiura	Abdominal pain, diarrhea, anemia, weight loss
Toxocara canis	Fever, muscle aches, neurological symptoms
Necator americanus	Hookworm disease

Nutrients are elements required for plant growth that provide biosolids with most of their economic value. These include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), sulfur (S), boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). Concentrations in biosolids can vary significantly (Table 3); thus, the actual material being considered for land application should be analyzed.

Trace elements are found in low concentrations in biosolids. The trace elements of interest in biosolids are those commonly referred to as "heavy metals." Some of these trace elements (e.g., copper, molybdenum, and zinc) are nutrients needed for plant growth in low concentrations, but all of these elements can be toxic to humans, animals, or plants at high concentrations. Possible hazards associated with a build up of trace elements in the soil include their potential to cause phytotoxicity (i.e., injury to plants) or to increase the concentration of potentially hazardous substances in the food chain. Federal and state regulations have established standards for the following nine trace elements: arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn).

Organic chemicals are complex compounds that include man-made chemicals from industrial wastes, household products, and pesticides. Many of these compounds are toxic or carcinogenic to organisms exposed to critical concentrations over certain periods of time, but most are found at such low concentrations in biosolids that the EPA concluded they do not pose significant human health or environmental threats. Although no organic pollutants are included in the current federal biosolids regulations, further assessment of several specific organic compounds (e.g., dioxins, PCBs) is being conducted.

Biosolids can be considered as a waste to be disposed of or as a beneficial soil amendment. Ocean dumping, a disposal practice common in the 1980's, was banned due to concerns about excess nutrient loading in these waters. Presently, about half of the biosolids generated in Virginia are applied to land and the remainder are disposed of through landfilling or incineration.

Landfill disposal

Landfill disposal offers the simplest solution to biosolids handling by concentrating the material in a single location. The risk of release of biosolids-borne pollutants and pathogens is minimal if the landfill is properly constructed and maintained. Economically, the cost compares favorably with other options.

Landfill disposal is not, however, without risks. Buried organic wastes undergo anaerobic decomposition which produces methane gas. Methane is a greenhouse gas whose release to the atmosphere has been implicated in possible global warming. The chemicals and nutrients can pose risk to local groundwater from older landfills that do not have synthetic liners or from a liner in a newer landfill developing a leak. In addition, the potential benefits of the organic matter and plant nutrients in the biosolids are lost with landfilling.

Incineration

Incineration reduces the biosolids volume, kills pathogens, destroys most organic chemicals, and provides energy. The remaining ash is a stable, relatively inert, inorganic material that possesses 10 to 20% of the original volume. Trace elements are not destroyed during incineration, which increases their concentra-

Table 3
Typical nutrient concentrations[a] in biosolids from all processes[b] (adapted from Sommers, 1977)

Nutrient	No. of samples	Range	Mean
Total N (%)	191	<0.1-17.6	3.9
NH_4-N (%)	103	0.0005-6.7	0.65
NO_3-N (%)	45	0.0002-0.49	0.05
Total P (%)	189	<0.1-14.3	2.5
K (%)	192	0.02-2.64	0.40
Ca (%)	193	0.1-25.0	4.9

[a] Concentrations are on a dried solids basis.
[b] Processes include anaerobically and aerobically digested, lagooned, primary, tertiary, and unspecified biosolids.

tions in the ash by five to ten-fold.

Incineration releases carbon dioxide (another greenhouse gas). Incineration is one of the more expensive options for biosolids disposal because it requires sophisticated systems to remove fine particulate matter (fly ash) and volatile pollutants from stack gases. Furthermore, the ash containing the higher trace element concentrations must usually be landfilled. As with landfilling, the potential benefits of organic matter and plant nutrient recycling are lost.

Land application (beneficial use)

As an alternative to disposal by landfilling or incineration, land application seeks to beneficially recycle the soil property-enhancing constituents in biosolids, which are ultimately derived from crops grown on agricultural land. Biosolids are about 50 percent mineral and 50 percent organic matter. The mineral matter includes plant nutrients, and organic matter is a source of slow release nutrients and soil conditioners. Land application returns those materials to the soil where they can contribute to further crop production.

Farmers can benefit from biosolids application by reducing fertilizer costs. The main fertilizer benefits are through the supply of nitrogen, phosphorus and lime (where lime-stabilized biosolids are applied). Biosolids also ensure against unforeseen nutrient shortages by supplying essential plant nutrients that are rarely purchased by farmers because crop responses to their application are unpredictable. These include elements such as sulfur, manganese, zinc, copper, iron, molybdenum, and boron.

Land application replenishes valuable organic matter, which occurs in less than optimum amounts in most Virginia soils. The addition of organic matter can improve soil tilth, the physical condition of soil as related to its ease of tillage, fitness as a seedbed, and its impedance to seedling emergence and root penetration. Other benefits imparted by the addition of organic matter to soil include:

- increases water infiltration into the soil and soil moisture-holding capacity
- reduces soil compaction
- increases the ability of the soil to retain and provide nutrients
- reduces soil acidification
- provides an energy source (carbon) for beneficial microorganisms

The addition of organic matter in biosolids to a fine-textured clay soil can help make the soil more friable and can increase the amount of pore space available for root growth and entry of water and air into the soil. In coarse-textured sandy soils, organic residues in biosolids can increase the water-holding capacity of the soil and provide chemical sites for nutrient exchange and adsorption.

Land application is usually less expensive than alternative methods of disposal. Consequently, wastewater treatment facilities and the public they serve benefit through cost savings. The recycling of nutrients and organic matter can be attractive to citizens concerned with environmental protection and resource conservation.

Land application of biosolids involves some risks, which are addressed through federal and state regulatory programs. Pollutants and pathogens are added to soil with organic matter and nutrients. Human and animal health, soil quality, plant growth and water quality could be adversely affected if land application is not conducted in an agronomically and environmentally sound manner. In addition, nitrogen and phosphorus in biosolids, as in any fertilizer source, can contaminate ground and surface water if the material is overapplied or improperly applied. There are risks and benefits to each method of biosolids disposal and use.

Further information can be found in the following Virginia Cooperative Extension fact sheets on agricultural land application of biosolids in Virginia: VCE Publication 452-302, Regulations (Evanylo, 1999b), VCE Publication 452-303, Managing biosolids for agricultural use (Evanylo, 1999c), and VCE Publication 452-304, Risks and concerns (Evanylo, 1999d).

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