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Biosolids recycling on crop- and rangeland

K.A. Barbarick and D.G. Westfall[1]

Quick Facts

Application of sewage biosolids to crop- or rangeland is a viable means to recycle this valuable resource.

Biosolids supply N, other plant nutrients, and organic matter to soils.

Necessary steps in a biosolids application program include:

1. File a Letter of Intent with the Colorado Department of Health (CDH).
2. Meet all CDH requirements regarding trace elements and pathogens.
3. Apply biosolids at "agronomic rates".
4. Develop a soil-management program that includes periodic soil and plant sampling and analyses.

Households, businesses, and industries produce wastewater. **Biosolids** are by-products of the wastewater-treatment process. Farmers, land-reclamation specialists, landscapers, and home gardeners have used these primarily organic materials for over seven decades in the United States.

The Colorado Department of Health (CDH) and the U.S. Environmental Protection Agency (USEPA) encourage and regulate recycling of biosolids on crop- or rangeland, since they contain plant nutrients and organic matter that can improve crop- and rangeland production as well as soil-physical conditions.

The CDH (1993) defines **biosolids** as:

"The accumulated residual product resulting from a domestic wastewater treatment works. Biosolids does not include grit or screenings from a wastewater treatment works, grease, commercial or industrial sludges, or domestic or industrial septage."

The (USEPA) announced final national standards (40 CFR Part 503) for beneficial use of biosolids on February 19, 1993. The CDH adopted their regulations (1993) in accordance with USEPA standards on November 2, 1993. All biosolids recycling and disposal programs must comply with state and federal regulations to protect the environment and public health.

To land-apply biosolids, you must first submit a Letter of Intent to CDH to develop a land-application program. The CDH will either issue or deny a Notice of Authorization for the plan detailed in a Letter of Intent.

A key aspect of USEPA and CDH regulations requires application of biosolids at an **agronomic rate**. The CDH (1993) defines agronomic rate as:

"The rate at which biosolids are applied to land such that the amount of nitrogen required by the food crop, feed crop, fiber crop, cover crop or vegetation grown on the land is supplied over a defined growth period, and such that the amount of nitrogen in the biosolids which passes below the root zone of the crop or vegetation grown to groundwater is minimized."

This information provided by:

[1]*K.A. Barbarick, Colorado State University professor and D.G. Westfall, professor; soil and crop sciences (revised 7/94).*

Biosolids Properties

Biosolids can exhibit a wide array of physical and chemical traits. Depending on the extent of dewatering or drying, the solids content of biosolids can range from less than 5 percent to more than 90 percent. Chemical characteristics of biosolids vary between treatment plants and, to a limited extent, within the same plant over time.

Table 1 lists the chemical composition of three Colorado biosolids as representative examples. Because biosolids may contain trace elements, they are classified by their trace-element content due to their potential impact on public health and the environment.

New, aggressive pretreatment programs at the source of generation have dramatically reduced metal concentration in biosolids over the last two decades; minimizing the possibility of environmental damages.

The USEPA and CDH established guidelines regarding the quantity of trace elements in biosolids and the amount that ultimately can be added to soils growing plants. The CDH (1993) also classifies biosolids into Grade 1 and Grade 2, depending on their metal concentrations (Table 2). These agencies base the metal limits on extensive research regarding the effects of biosolids metals on various pathways of exposure, including plant toxicities and adverse effects on animal and human health.

Biosolids are treated to eliminate pathogens (disease-causing organisms) that may reside in wastewater. USEPA and CDH (1993) require domestic wastewater treatment plants to reduce pathogens and diminish the attraction of insects and animals before biosolids are land applied.

In Colorado, anaerobic (without air) digestion and aerobic digestion (with air) are the most common methods used to treat and stabilize biosolids. Digestion destroys pathogens through heat and attack by beneficial microorganisms (e.g., anaerobic bacteria); it also reduces odors. Municipalities use composting, heat drying, and other techniques to further reduce pathogens and stabilize the material.

Table 1: Chemical properties (dry weight basis) of three biosolids from Colorado.

Parameter, units	Littleton/ Englewood[†]	Fort Collins[‡]	Metro Denver[§]
EC[¶], dS/m	11.6	5.0	12.7
Organic N, %	2.88	4.22	6.31
NH_4-N, %	0.47	0.40	1.35
NO_3-N, %	0.01	0.01	0.01
Phosphorus (P), %	2.52	1.60	2.32
Potassium (K), %	0.283	0.194	0.200
Arsenic (As), mg/kg	4	3	3
Cadmium (Cd), mg/kg	6	5	10
Chromium (Cr), mg/kg	98	40	80
Copper (Cu), mg/kg	558	553	500
Mercury (Hg), mg/kg	0.8	6.2	3.0
Lead (Pb), mg/kg	45	117	138
Molybdenum (Mo), mg/kg	26	16	31
Nickel (Ni), mg/kg	85	19	41
Selenium (Se), mg/kg	13	14	4
Zinc (Zn), mg/kg	942	776	915

[†] Applied to experimental plots near Bennett, CO in August 1993.
[‡] Applied to experimental plots on the Meadow Springs Ranch near Fort Collins, CO in August 1991.
[§] Metrogro™ cake chemical analysis, 1993.
[¶] EC is a measure of the soluble salt concentration.

Table 2: Maximum trace element concentrations allowed by CDH (1993) for Grade 1 and Grade 2 biosolids.

Metal	Grade 1	Grade 2
	— mg/kg (dry weight basis) —	
As	41	75
Cd	39	85
Cr	1200	3000
Cu	1500	4300
Pb	300	840
Hg	17	57
Mo	Not finalized	75
Ni	420	420
Se	36	100
Zn	2800	7500

Applicators may apply Grade 1 biosolids at agronomic rates without restrictions regarding trace metal loading limits. However, CDH and USEPA limit the annual and cumulative application of Grade 2 biosolids according to the annual and lifetime (cumulative) loading limits in Table 3.

Table 3: Annual and cumulative pollutant loading limits (CDH, 1993).

Metal	Annual limit	Cumulative limit
	— lbs/Ac[†] —	
As	1.8	37
Cd	1.7	35
Cr	139	2680
Cu	67	1340
Pb	14	268
Hg	0.75	15
Mo	0.80	16
Ni	19	375
Se	4.5	89
Zn	125	2500

[†] kg/ha = 1.12 * lbs/Ac

Fertilizer and Soil Amendment Value

Biosolids contain significant amounts of N, P, and K (Table 1). They also can provide plant micronutrients such as Zn. Many soils in Colorado exhibit low levels of plant-available Zn and biosolids help alleviate the deficiency of this essential element.

The nature of nutrients in biosolids is different than those found in commercial fertilizers. Stabilization of biosolids during waste treatment produces organic N forms that are not available to plants until they are decomposed by soil microorganisms. When added to soils, microorganisms break down biosolids and release 10 percent to 50 percent of the organic N as a plant-available N form (ammonium, NH_4^+) in the first year following application. Soil microorganisms rapidly convert the NH_4^+ to nitrate (NO_3^-); plants quickly absorb NO_3^-; but, it also is mobile in soils, irrespective of whether it originates from commercial N fertilizer or biosolids. The mobility of NO_3^- increases the potential for groundwater contamination. In essence, biosolids are slow-release N fertilizers that contain low concentrations of plant nutrients.

Soil physical changes that biosolids promote frequently are more significant than the plant nutrients supplied. Most Colorado soils contain less than 1.5 percent organic matter. Biosolids can serve as a source of organic material that improves soil tilth, water-holding capacity, structure development and stability, air and water transport and ultimately decrease soil erosion potential.

Cropland Application

Colorado State University has applied Littleton/Englewood biosolids to summer-fallowed dryland winter wheat near Bennett, Colorado for 13 years. Continuous application of 3 dry tons/acre of biosolids, when compared to 50 pounds or 60 pounds of N/acre as commercial N fertilizer, produced comparable or better wheat yields, larger protein contents, and larger economic return (Barbarick et al., 1991; Barbarick et al., 1992; Ippolito et al., 1992, 1993, 1994).

The greatest challenge in using biosolids for beneficial reuse on crop- and rangeland is to prevent NO_3^- leaching to groundwater. As biosolids' nutrient value may vary depending on the form (i.e., liquid, dewatered, or dried), determining the correct agronomic rate remains a challenge.

However, if the agronomic rate is applied under non-irrigated (dryland) cropping in our semi-arid environment where water table depths generally are over 100 feet deep, the potential for groundwater contamination is negligible. Under irrigated conditions, if agronomic rates of biosolids based on site specific soil-test and crop-management information are applied, groundwater contamination with NO_3^- should not occur. Annual monitoring of residual soil NO_3-N levels will help guard against groundwater pollution.

Rangeland Application

Recent interest in the use of biosolids on rangeland has developed. Harris-Pierce et al. (1993) found that surface application, without subsequent incorporation of 2 dry tons/acre of biosolids from the Fort Collins wastewater-treatment facility, increased plant canopy cover of rangeland in the first and second seasons following application. Five dry tons/acre increased plant biomass production compared to untreated control plots in just the first season. The interaction of climate and biosolids application did produce some shifts in plant species distribution.

Since biosolids application to rangeland generally involves surface application without incorporation, the effect of biosolids addition on runoff-water quality is a concern.

In a simulated rainfall study (water was applied through a sprinkler system) on 8 percent and 15 percent slopes, Harris-Pierce et al. (1993) found that under a severe runoff event (4 inches rainfall/hour), an estimated rate of 1.5 dry tons/acre biosolids application would not create any potential NO_3-N or trace element pollution problems. If off-site transport is possible, it may be minimized by providing untreated buffer strips around areas of runoff catchment and along edges of drainage ways.

Public Acceptance

Land application of biosolids for beneficial use poses no health or environmental threat if CDH and USEPA guidelines for trace elements and pathogens are followed and proper soil management is practiced.

Biosolids application also will result in beneficial economic return to agricultural producers and improve soil quality. Municipal pretreatment programs significantly reduce the metal content in biosolids. Proper treatment (i.e., anaerobic digestion) of sewage eliminates most pathogens. Further treatment such as drying, composting, and lime stabilization further reduce pathogens.

Some public defiance of biosolids application will probably always exist. Applicators must face issues about odors, fears about health and environmental risks, and act appropriately to ensure odors are minimized and biosolids are handled and applied safely and aesthetically.

Public education should continue to develop trust between all parties. Society can benefit if we can safely recycle the plant nutrients and organic material that constitute biosolids.

Steps for a Successful Land-Application Program

1. Letter of Intent for CDH.
2. Know the nutrient and trace-metal composition of the biosolids.
3. Prior to application and for each application hereafter, applicators must sample and analyze the soil from the land application site for pH, NH_4-N, NO_3-N, total P, conductivity (measure of soil salinity), organic matter, and available P. Applicators must also collect and analyze soils for As, Cd, Cr, Cu, Pb, Hg, Mo, Ni, Se, and Zn once every five years after application.
4. Include a soil-fertility evaluation in the soil analyses, especially for N, so that the applicator can ascertain the agronomic rate of the biosolids. Over the long term, using soil test data will help prevent an imbalance of plant nutrients.
5. Judiciously apply biosolids to sloping land to avoid surface water contamination.
6. Contact CDH or USEPA to ensure that you meet all necessary requirements for biosolids use. Only CDH can approve a program of recycling of biosolids through land application.

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