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Manual of Best Management Practices for Land Application of Biosolids

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Introduction

For centuries, farmers have used animal manures to improve soil fertility. In the 1920s, farmers in the U.S. began to use the semi-solid byproduct of wastewater treatment known as "wastewater solids" or "sewage sludge" as a fertilizer. Through decades of research, the scientific and agricultural communities have come to understand that this material is also a valuable source of nutrients and organic matter for improving the soil. It is important to understand that what is applied to soils today is not raw sewage or sewage sludge. According to federal regulations, only sewage sludge that is treated, tested, and meets regulatory standards can be land applied. This treated material is commonly called "biosolids"[1]. Nationwide, most (~55%) of the 7.18 million U. S. dry tons of sewage sludge produced is land applied (NEBRA, 2007).

Land application of biosolids can be a cost-effective way to support agricultural production.

While raw sewage contains pathogens, biosolids approved for land application have been treated to significantly reduce pathogens. Class A biosolids have been treated to eliminate pathogens; they are safe for public use with no further regulation. Class B biosolids contain pathogens at levels similar to or less than untreated animal manures. Use of Class B biosolids in New Hampshire requires a site permit from DES and management measures that ensure remaining pathogens do not create a risk to human health. The 503 and state regulations require Class B biosolids be incorporated into the soil, or site access be restricted for surface-applied biosolids, to minimize potential exposure. The research on pathogens in land-applied biosolids has not found problems with disease transmission.

Best Management Practices prevent agricultural nutrients from contaminating water resources.

Biosolids, septage, and manures contain various natural and synthetic chemicals. Biosolids can contain a larger variety of synthetic chemicals, such as pharmaceuticals and personal care product chemicals. Research regarding these traces of biosolids-borne chemicals on soil biota, plants, crops, animals, and food have not found significant impacts under real-world field conditions (e.g Puddephat, 2013).

[1]In New Hampshire, "biosolids" is defined by RSA 485-A:2, XX11 and Env-Wq 800, as "any sludge derived from a sewage wastewater treatment plant that meets the standards for beneficial reuse specified by the department" [of Environmental Services].

Focused research on the use of biosolids on soils originated in the 1970s. Research conducted at UNH in the 1990s by Thomas Buob, George O. Estes, James Mitchell, and David Seavey, informed the original *Best Management Practices* published by University of New Hampshire (UNH) Cooperative Extension in 1995. Additional UNH research conducted in the early 2000s by William McDowell and Thomas Ballestero provided additional understanding of best management practices and application rates.

A U. S. Environmental Protection Agency (EPA) regulation, *The Standards for the Use or Disposal of Sewage Sludge* (40 CFR Part 503) was published in the Federal Register on February 19, 1993 and became effective on March 22, 1993. In 1996, the New Hampshire Department of Environmental Services (DES) adopted regulations for the management of sludge in New Hampshire. These rules have been updated periodically. Env-Wq 800 establishes a permit system to regulate the transportation and disposal of sludge or beneficial use of biosolids through land application. In preparing this Best Management Practices publication, the above regulations have been carefully considered.

Land application of biosolids is an expanding, cost-effective option that offers a cost-effective source of nutrients to help maintain soil fertility. However, public acceptance, odors, and nutrient imbalances that don't not always align with crop needs highlights the need for careful management. Effective land stewardship requires thoughtful planning and adherence to accepted responsible practices, just as with any other source of crop nutrients.

Purpose of these Best Management Practices

The development and use of Best Management Practices (BMPs) is of paramount importance if products such as food processing wastes, biosolids, and/or septage are to be applied to cropland. The chemical and pathogen quality of such products is regulated by Env-Wq 800 and similar regulations of DES, which protect public health and environmental quality. These BMPs are necessary to ensure that nutrients, soils, and cropping systems are properly managed to ensure maximum benefits without putting soil and water resources at risk. This publication is intended to offer best management practices to guide responsible use of biosolids.

Biosolids as a Source of Plant Nutrients

The N, P and K contributions from biosolids are valuable in crop production, and land application of municipal biosolids offers opportunities for both nutrient enrichment and organic matter improvement to soils. Only biosolids that are nutrient-rich, stabilized to significantly reduce pathogens and low in metals are suitable soil amendments.

Biosolids typically contain 2 - 6% total N (with lower nitrogen in composted biosolids), and typically have over 90% of their total nitrogen in the organic form which is mineralized to plant-available nitrate nitrogen (NO_3-N) by microbial activity. Since the rate of mineralization is governed by soil moisture and temperature, the quantity of NO_3-N supplied from a broadcast, pre-plant, soil incorporated application of biosolids is difficult to predict. Ongoing research continues to refine the amount of nitrogen available from different biosolids products in the first and subsequent years after application.

Phosphorus (P): Biosolids typically contain 1 – 3% total P. As with many animal manures, the ratio of plant-available nitrogen to phosphorus in biosolids is lower than the amounts typically taken up by plants. Therefore, basing application rates on nitrogen may result in phosphorus applications in excess of crop requirements. Consequently, there is a risk that, after repeated applications of biosolids and/or animal manures, phosphorus-enriched sediment can run off the soil surface and end up in surface waters, where they pose a risk to water quality. The use of Best Management Practices (BMPs) will help optimize crop use of N and P while minimizing losses to the environment, particularly NO_3-N losses to groundwater and phosphorus to surface waters.

The nutrient and metal concentrations in biosolids are highly variable. Chemical comparison of selected biosolids is given in Table 1 for nutrients and regulated metals along with EPA standards for metals.

Table 1. Total elemental composition of wastewater biosolids from a number of municipalities in the U.S.[a] and lime-stabilized biosolids from Concord, N.H.[b] compared to DES maximum permissible limits for metals in biosolids.

		Franklin[a]	Concord[a]	Merrimack[a]
% Total Solids		23.7	36.1	59.4
Total Nitrogen (mg/kg)		51,794	33,409	15,090
NH_4- Nitrogen (mg/kg)		8,174	2,665	6,278
$NO_3 + NO_2$- Nitrogen (mg/kg)		730	1,526	103
Organic Nitrogen (mg/kg)		42,666	30,725	8,847
Total Potassium (mg/kg)		1,424	1,993	2,855
Total Phosphorus (mg/kg)		19,427	8,438	3,839
		Average[b]	DES Limits	Range[b]
	←	mg/kg (ppm)		→
		Ceiling Concentration	Low Metals Limit	
Arsenic	5.2	32	10	0.0 - 12.6
Cadmium	3.2	14	10	1.9 - 4.4
Chromium (Total)	26.3	1,000	160	16.2 - 35.0
Copper	393	1,500	1,000	253-553
Lead	35.6	300	270	19.8 - 59.3
Mercury	1.8	10	7	0.27 - 5.55
Molybdenum	11.0	35	18	3.8 - 20.5
Nickel	21.1	200	98	11.6-43.4
Selenium	3.8	282	18	0.0 - 6.5
Zinc	723	2,500	1,780	485 - 1,399

a. N.H. Department of Environmental Services, Analytical data from wastewater treatment facilities in Franklin, Concord, and Merrimack 1999-2010.
b. Data from NHDES sampling of POTW land appliers, 2001-2013.

Heavy metals of concern in biosolids include arsenic (As), cadmium (Cd), copper (Cu), chromium (Cr), lead (Pb), mercury (Hg), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn). Mineral soils ordinarily contain low concentrations of heavy metals. The typical concentrations of metals in manures and New Hampshire biosolids, along with mean concentrations of these metals in soils, are shown in Table 2.

Table 2. Mean concentrations of elements (metals) of concern in soils, manures, and biosolids (mg/kg dry weight).

	1	2	3	4	5	6	7	8
Metal	**U.S. Soils, A Horizon, Planted/ Cultivated (i.e. plow layer)**	**Dairy Cattle Manure**	**Poultry Manure**	**Concord biosolids (lime-stabilized)**	**Nashua biosolids (anaerobic digested)**	**U.S. EPA Part 503 Table 3 (low metals, NOAEL)**	**NH DES regulatory limit**	**NH DES "low metals" regulatory limit (not risk based)**
Arsenic (As)	6.29		13	2.5	14.6	41	32	10
Cadmium (Cd)	0.25	0.25	2.4	0.8	1.6	39	14	10
Chromium (Cr)	33.01			8	87.3	NS	1,000	160
Copper (Cu)	19.39	38	465	114	590	1,500	1,500	1,000
Lead (Pb)	20.12		46	11	46.2	300	300	270
Mercury (Hg)	0.03			0.41	0.8	17	10	7
Molybdenum (Mo)	0.93	6.2	19	2.9	10.9	NS	35	18
Nickel (Ni)	15.52	23	16	5	27.3	420	200	98
Selenium (Se)	0.38			1.80	5.4	36	28	18
Zinc (Zn)	58.85	150	602	236	1,409	2,800	2,500	1,780

Sources:

Column 1: Smith et al., 2013 (n = 1543; test results below detection limits are included as equal to the detection limit); Columns 2 and 3: Moss et al., 2000, from American Society of Agricultural Engineers, 2000; Column 4: Concord NH WWTF 2013-2014 (n = 19; test results below detection limits are included as equal to the detection limit); Column 5: Nashua NH WWTF 2013-2014 (n = 15; test results below detection limits are included as equal to the detection limit); Column 6: NOAEL = no observed adverse effect level; NS = no standard.

Any land application of biosolids or septage should avoid elevated soil levels of regulated metals that could potentially jeopardize the production of crops for human and animal consumption. One of the most important findings of biosolids research is a conclusion that permits definition of low metal biosolids as having "no observed adverse effect level" (NOAEL) quality biosolids (Chaney 1990). These biosolids have especially low risk to land and crops and represent a technical basis for application criteria in the Clean Water Act Part 503 Regulation. Today in the U. S., because of required industrial pretreatment programs, most municipal sewage sludges, including all biosolids land applied in New Hampshire, meet the most stringent federal standards (Table 3 of 40 CFR Part 503).

Best Management Practices for Biosolids

Site and Soils

Biosolids are typically applied to agricultural fields of greater than 10 acres with gentle slopes. Site selection is guided by DES regulations (Env-Wq 800), and a site plan is required as part of the site permitting process for Class B biosolids use. Site plans and DES regulations address soil testing, setbacks from wells, surface waters, bedrock, groundwater, etc. and prohibit biosolids application on steep slopes.

- Application sites in aquifer recharge areas may require extra nutrient management controls.
- Avoid biosolids application on land that frequently floods or on sites with high water tables or on slopes likely to have surface runoff. Do not apply during periods of high water table.
- Consider the soil's base saturation to avoid imbalances of base cations (Ca, Mg, and K).
- Erosion control measures, such as establishing cover crops for the fall and winter, should be used with tilled soils in order to prevent surface runoff.
- Soil variability should be evaluated when selecting a site.
- Env-Wq 800, DES has established buffer distances from surface waters, wells, and groundwater. Biosolids should not be surface applied within 125 feet from any surface water. If biosolids are incorporated into the soil within 24 hours, they may be applied within 75 feet from surface waters, or 33 feet from intermittent streams or drainage ditches.
- Biosolids should not be applied to the land within 300 feet of any private well and 500 feet from any community well or municipal water supply well. Biosolids should not be applied during periods of high water table. Two feet of separation from groundwater must be maintained at the time when biosolids are applied.

Crop Considerations

The ideal crop will exhibit minimal uptake of metals and display significant benefit from the nutrients in biosolids. This would include non-agricultural land (e.g. landfills, turf, or roadside restoration) as well as field crops grown for animal feed (e.g. field corn grown for silage or grain, and forage crops).

Fall maintenance applications are preferred for forage crops (including hay, pasture, field corn, and small grains) and should be made before the ground freezes. The preferred application time is immediately after forage harvest. Allow at least 45 days between application and harvest or grazing to preserve animal acceptability. The ideal practice is to make topdressing applications prior to anticipated rainfall. Incorporate biosolids prior to tillage whenever possible.

Avoid biosolids applications to land where food crops are grown. Leaf and root crops are the greatest accumulators of heavy metals. Careful mannagement and monitoring of the soil and crop is critical (Hermanson et.al. 1987).

Application Planning

Improper application of biosolids to soils may limit their use for certain crops in the future. Loading rate of soils should be governed first by crop needs, taking care that biosolids applications do not result in excess nitrate leaching or in raising soil test phosphorus to excessive levels. If soil test phosphorus is already rated very high or excessive, additional phosphorus loading from biosolids may not be appropriate.

One of the special concerns associated with any biosolids which is to be land applied relates to the processes to reduce pathogens, one of which is short-term lime stabilization. This method involves raising the pH to 12 for a short period of time. Hydrated lime is often used to achieve this rapid pH elevation. Use of such stabilized biosolids on agricultural land, therefore, involves a high pH material containing large amounts of readily available calcium. With repeated use, soil pH may increase above the desirable range, in turn affecting the availability of nutrients and the efficacy of such crop inputs as herbicides. It is possible that calcium, rather than nitrogen loading, will pose the most limiting factor in using biosolids and septage on agricultural land. Research data (McLean et.al., 1983) show results that "strongly suggest that for maximum crop yields, emphasis should be placed on providing sufficient, but not excessive levels of each basic cation". Suggested soil cation saturation ratios of the cation exchange capacity (CEC) from many literature sources support a base saturation of 3-6% potassium, 12-13% magnesium, and 65-80% calcium. Soil pH should be maintained above 6.5 in order to limit the solubility of metals, but should not exceed 7.2.

- When possible, biosolids spreading should be done when weather conditions allow rapid odor dissipation.
- Annual biosolids loading rates and supplemental fertilizer requirements are based on biosolids and soil analysis. Total available nitrogen in a given year should not exceed crop requirements. On sites with a high risk of soil erosion, biosolids applications should not provide phosphorus in excess of crop removal if soil test phosphorus levels are already high.
- Estimate the crop nutrient needs given the farm's yield goals.
- Calculate the agronomic application rate using the UNH Cooperative Extension Nutrient Management Worksheet for Biosolids (2015).
- The choice of land application equipment is determined by the physical characteristics of the biosolids. Equipment should be calibrated to insure uniform accurate rates of application.
- Biosolids should be spread evenly over the ground and incorporated within 24 hours by discing or plowing whenever possible.
- Heavy equipment should not be used when the soil is wet in order to minimize soil compaction.
- Biosolids should not be applied on soils that are frozen, excessively wet or covered with snow.
- Alkaline-stabilized biosolids should not be applied at rates greater than the soil liming requirements, and the nutrients present in the product (N, P) must be accounted for, even if the application is based solely on the liming value.

Storage

- Take precautions to minimize odors and leaching losses.
- Select appropriate stockpile locations: level ground with low risk of excessive leaching or ponding of water.
- According to DES rules, on-site storage (stockpiling) should adhere to the following setbacks:
- 500 feet from dwellings or private water supply;
- 100 feet from property lines.
- Strict access control is necessary.
- Stockpiles should be spread within an eight-month period.

Monitoring and Recordkeeping

Although state permits are required for land application of biosolids, good stewardship requires a program of site monitoring. DES currently requires annual soil testing to assess soil fertility and testing every five years to evaluate heavy metals loading to the soil. This can help assess the nutrient and metal loading effects during the application period as well as after the site has reached its loading capacity. Major considerations include the potential loss of nitrogen and metals as non-point source pollutants and the development of nutrient imbalances which may have negative effects on long term crop production.

Good recordkeeping is crucial to a successful land application program. In the long term production of any crop field records are an indispensable tool in evaluating the effects of nutrient (fertilizers, manures and biosolids) applications on soil fertility and crop response. In order to evaluate the effectiveness of biosolids applications complete records (soil test results, recommendations, applications rates, nutrient analysis, etc.) are a necessary portion of every land application program. Elements of an effective monitoring plan include:

- Complete soil analysis prior to each biosolids application through the UNH Soil Testing program, or through another accredited soil testing program. In addition to standard soil test results (pH, nutrient levels, organic matter), UNH Cooperative Extension recommends including an environmental package to monitor heavy metals.
- Use of midseason tests (e.g. pre-sidedress nitrate test, Adapt-N model, chlorophyll meters) to refine nitrogen needs in annual row crops. In order to better safeguard the drinking water standards, producers must consider the amount of nitrogen mineralized from soil organic matter that contributes to the crop's nitrogen requirement. A fall soil nitrate test may be needed to adjust application rates in instances where a water quality concern exists.
- Mineral analysis of feed crops from fields which have received repeated applications of biosolids is recommended to enhance dairy ration balancing.
- Complete cropping records kept on individual fields to help evaluate the effects of the land application program on crop production.
- Farmers should keep records of the source, quantity and quality of materials applied. Records should be kept of when, how, and by whom biosolids are applied, as well as any concerns (such as odors, etc.) noted during application.

Cover crops reduce the risk of nutrient losses from runoff and leaching.

References

Brandt, R.C., H.A. Elliott, and G.A. O'Connor. 2004. Water-Extractable Phosphorus in Biosolids: Implications for Land-Based Recycling. *Water Environment Research.* 76(2):121-129.

Brown et al. 2005. An interlaboratory study to test the ability of amendments to reduce the availability of Cd, Pb and Zn in situ. *Environmental Pollution*. 138:34-45.

Brown, Chaney, Hallfrisch and Xue, 2003. Effect of biosolids processing on lead bioavailability in an urban soil. *Journal of Env. Quality*. 32:100-108.

Chaney, Rufus L., September 1990. *Twenty Years of Land Application Research*. BioCycle. 31(9):54-59.

Chaney, Rufus L., October 1990. *Public Health and Sludge Utilization*. BioCycle. 31(10):68-73.

DeVolder et al, 2003. Metal bioavailability and speciation in a wetland tailings repository amended with biosolids compost, wood ash and sulfate. *Journal of Env. Quality*. 32:851-864.

Douglas, B.F. and F.R. Magdoff. 1991. *An Evaluation of Nitrogen Mineralization Indices for Organic Residues*. J. Environ. Qual. 20:368-372.

Elliott, H.A., R.C. Brandt, P.J.A. Kleinman, A.N. Sharpley, and D.B. Beegle. 2005. Estimating source coefficients for phosphorus source indices. *Journal of Environmental Quality*. 35:2195-2201.

Hermanson, R.E., C. Cogger and C. Engle. 1987. *Sewage Sludge Guidelines for Washington*. Part One: Application to Farmland. Part Two: Site Selection and Management. Part Three: Sample Problem and Worksheet for Calculating Biosolids Application Rates.

Gilmour, John T.; Craig G. Cogger; Lee W. Jacobs, Gregory K. Evanylo; and Dan M. Sullivan. 2000. Decomposition and Plant-Available Nitrogen in Biosolids. *J. Environ. Qual.* 32: 1498–1507.

Klausner, S. and D. Bouldin. March 1983. *Managing Animal Manure as a Resource*. Part II: Field Management. Department of Agronomy Cornell University.

Loehr, Raymond C.(ed.).1976. *Land as a Waste Management Alternative*. Ann Arbor Science Publishers luc., P.O. Box 1425. Ann Arbor, Michigan 48106.

Mathers, A.C. and D.W. Goss 1979. *Estimating Animal Waste Applications to Supply Crop Nitrogen Requirements*. Soil Sci. Soc. Am. J. 43:364-366.

McKeague, J.A. and M.S. Worynetz. 1980. Background Levels of Minor Elements in Some Canadian Soils. Geoderma. 24:299-307.

McLean, E.O., R.C. Hartwig, D.J. Eckert and G.B. Triplett. 1983. *Basic Cation Saturation Ratios as a Basis for Fertilizing and Liming Agronomic Crops 11. Field studies*. Agronomy Journal. 75:635- 639.

Mitchell, J.R. 1990. *Best Management Practices - Nutrients*. University of New Hampshire Cooperative Extension.

Moss, L.; E. Epstein; and T. Logan. 2000. *Evaluating Risks and Benefits of Soil Amendments Used in Agriculture*. Alexandria, VA: Water Environment Research Foundation.

National Research Council. 1996. *Use of Reclaimed Water and Sludge in Food Crop Production*. National Academy of Sciences.

NIOSH (National Institute for Occupational Safety and Health). 2002. *Guidance for Controlling Potential Risks to Workers Exposed to Class B Biosolids*.

Nutrient Requirements for Dairy Cattle. Sixth Revised Edition.1989. National Academy Press. Washington,D.C. 1988.

Puddephatt, Karen Joan, "Determining the Sustainability of Land-Applying Biosolids to Agricultural Lands Using Environmentally-Relevant Terrestrial Biota" (2013). Ryerson University: Theses and dissertations, Paper 1579.

Sabourin, Lyne; Peter Duenk; Shelly Bonte-Gelok; Michael Payne; David R. Lapen; and Edward Topp. 2012. Uptake of pharmaceuticals, hormones and parabens into vegetables grown in soil fertilized with municipal biosolids. *Science of the Total Environment*. 431 (2012) 233–236.

Smith, David B.; William F. Cannon; Laurel G. Woodruff; Federico Solano; James E. Kilburn; and David L. Fey. 2013. *Geochemical and Mineralogical Data for Soils of the Conterminous United States*. U. S. Geological Survey, Data Series 801.

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