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PART 2 — REFERENCE SHEETS

The following reference sheets provide pertinent information and additional references for several issues relevant to 40 CFR Part 503. Some of the reference sheets contain information directly related to compliance issues (*e.g.*, approved analytical methods), while the remaining sheets provide guidance for implementing 40 CFR Part 503. The topics presented may not be applicable to all, but should assist those who need additional information. The following table of contents lists the reference sheets provided.

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SECTION 2.1 C BIOSOLIDS ANALYSIS METHODS

40 CFR Part 503.8 contains a listing of approved analytical methods and volatile solids reduction calculations that must be used for monitoring biosolids quality. It is the responsibility of the permit holder, not the contract lab, to ensure that only EPA-approved analytical methods are used. Therefore, a POTW operator must be knowledgeable about which methods must be used for each specific analysis and, if needed, provide that information to the contract lab.

Table 2.1-1 presents the required analytical methods, the maximum allowable sample holding times, sample preservation techniques, sample containers, sample preparation methods, and additional comments that may be pertinent to the analytical method. Much of this information is repeated throughout this handbook, but Table 2.1-1 is intended to be used as a reference guide when preparing for sample collection and reviewing the delivered data summary package.

Several points must be made prior to reviewing the Table:

$ Laboratories often commit the analytical error of conducting metals analyses using analytical methods developed for water and wastewater. These methods include those in *Standard Methods for the Examination of Water and Wastewater* (a.k.a. *Standard Methods*) and various EPA methods in the 200 Series (*e.g.*., Method 206.2). For biosolids samples, all metals must be analyzed by SW-846 methods, which are found in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846).

$ Note that more than one SW-846 method is provided for each pollutant in metals analyses. The differences among the methods are usually the equipment used (*e.g.*, direct aspiration, furnace, or ICP scan) and the level of detection desired. Each of the methods listed in the table are approved for use under 40 CFR 503, but certain sample characteristics may require one to be used instead of another. Contact your laboratory regarding these choices.

$ SW-846 Methods 3050B or 3052 are the required preparation methods for all metals except mercury (using equivalent to 1 gram dry weight).

$ In contrast to the metals, many inorganic parameters (*e.g.*, nitrite, TKN, etc.) require methods which are found in *Standard Methods*. There are several reasons for this, the most important one being that there is no SW-846 method for the parameter specific to solid waste.

$ The SW-846 manual is published by the EPA Office of Solid Waste (OSW) and is intended to be a "living document," in that it is updated with some regularity to include new analytical methods for existing analytes, methods for new analytes, and revisions to existing methods that are designed to improve data quality and address difficult sample types. It is OSW's intent that the latest version of a given method be used whenever specified in a Resource Conservation and Recovery Act (RCRA) regulation.

Table 2.1-1. Approved Methods for the Analysis of Biosolids (40 CFR Part 503).

Pollutant	Analysis Method Description	Maximum Holding Time Sample Preservation Sample Container	Comments
Arsenic	AA Gaseous Hydride SW-846 Method 7061 AA Furnace SW-846 Method 7060A Inductively Coupled Plasma SW-846 Method 6010B	6 Months Cool 4EC Plastic or glass container Samples must be digested prior to analysis.	All samples must be digested using SW-846 Method 3050 (using equivalent to 1 gram dry weight) prior to analysis by any of the procedures indicated. Method 3051 can be used only with permission. The AA Direct Aspiration analyses are applicable at moderate concentration levels in clean complex matrix systems. AA Furnace methods can increase sensitivity if matrix effects are not severe. Inductively Coupled Plasma (ICP) methods are applicable over a broad linear range and are especially sensitive for refractory elements. Detection limits for AA Furnace methods are generally lower than for ICP methods.
Cadmium	AA Direct Aspiration SW-846 Method 7130 AA Furnace SW-846 Method 7131A Inductively Coupled Plasma SW-846 Method 6010B		
Chromium	AA Direct Aspiration SW-846 Method 7190 AA Furnace SW-846 Method 7191 Inductively Coupled Plasma SW-846 Method 6010B		
Copper	AA Direct Aspiration SW-846 Method 7210 Inductively Coupled Plasma SW-846 Method 6010B	6 Months Cool 4EC Plastic or glass container Samples must be digested prior to analysis.	All samples must be digested using SW-846 Method 3050 (using equivalent to 1 gram dry weight) prior to analysis by any of the procedures indicated. Method 3051 can be used only with permission. The AA Direct Aspiration analyses are applicable at moderate concentration levels in clean complex matrix systems. AA Furnace methods can increase sensitivity if matrix effects are not severe. Inductively Coupled Plasma (ICP) methods are applicable over a broad linear range and are especially sensitive for refractory elements.
Lead	AA Direct Aspiration SW-846 Method 7420 AA Furnace SW-846 7421 Inductively Coupled Plasma SW-846 Method 6010B		
Molybdenum	AA Furnace SW-846 Method 7481 Inductively Coupled Plasma SW-846 Method 6010B		

Pollutant	Analysis Method Description	Maximum Holding Time Sample Preservation Sample Container	Comments
Nickel	AA Direct Aspiration SW-846 Method 7520 Inductively Coupled Plasma SW-846 Method 6010B		Detection limits for AA Furnace methods are generally lower than for ICP methods.
Selenium	AA Furnace SW-846 Method 7740 Inductively Coupled Plasma SW-846 Method 6010B AA Gaseous Hydride SW-846 Method 7741		
Zinc	AA Direct Aspiration SW-846 Method 7950 Inductively Coupled Plasma SW-846 Method 6010B		
All metals samples must be prepared prior to analysis using SW846-Method 3050 or 3052.			
Mercury	Cold Vapor (manual) SW-846 Method 7470A SW-846 Method 7471A	28 days Cool 4EC Plastic or glass container Samples must be digested prior to analysis.	SW-846 Method 7470 applies to Mercury in liquid wastes. SW-846 Method 7471 applies to Mercury in solid or semisolid wastes. The digestion procedure is contained in the analytical method.
Fecal Coliform	SM-9221 C (MPN) SM-9222 D (Membrane Filter, MF)	6 hours Cool 4EC Plastic or glass container	Both procedures are very temperature sensitive. Samples must be analyzed within defined holding times. SM-9222 D is no longer allowed in Region VIII.
Salmonella, sp.	SM-9260 D.1 or Kenner	6 hours Cool 4EC Plastic or glass container	Large sample volumes are needed due to the low concentration of Salmonella in wastewater and biosolids. Also, due to the large number of Salmonella species, more than one procedure may be necessary to adequately determine the presence of Salmonella.

Pollutant	Analysis Method Description	Maximum Holding Time Sample Preservation Sample Container	Comments
Enteric Viruses	ASTM-Method D 4994-89	2 hours at up to 25EC or 48 hours at 2 to 10EC. No preservation Plastic or glass container	Concentration of sample is necessary due to the presumably low numbers of viruses in the sample.
Helminth Ova	Yanko	5 days Cool 4EC Plastic or glass container	Analyst must be familiar with other Ova test methods which are also found in this same document. Due to the complexity in determining viable Ova, all Ova identified will be considered viable.
Total, Fixed, and Volatile Solids	SM-2540 G	7 days Cool 4EC Plastic or glass container	Method 2540 G is the recommended procedure for solid and semisolid samples.
Specific Oxygen Uptake Rate (SOUR)	SM-2710 B	Perform as soon as possible No preservation Plastic or glass container	Quite sensitive to sample temperature variation and lag time between sample collection and test initiation. Replicate samples are suggested. SOUR must be calculated based on total solids (dry weight) rather than on volatile solids.
Total Volatile Acids	SM-5560 C	7 days Cool 4EC Plastic or glass container	Method C can be used as a control test for anaerobic digestion even though it gives somewhat variable recovery. Recovery factors should be determined.
Total Phosphorus	SM-4500-P	28 days Cool 4EC Plastic or glass container	Pay close attention to sample preparation requirements found in section 4500-P B.
pH	SW-9045A	Immediate No preservation Plastic or glass container	Sample is mixed with a prescribed liquid and pH determined with probe. Temperature fluctuations may cause measurement errors and the latest version of the method, 9045A,

Pollutant	Analysis Method Description	Maximum Holding Time Sample Preservation Sample Container	Comments
			addresses this issue by requiring that pH measurements be conducted at 25"1EC.
Conductivity	SW-9050A	28 days Cool 4EC Plastic or glass container	Sample should be measured at 25EC or temperature corrections made and results reported at 25EC.
Total Kjeldahl Nitrogen (TKN)	SM-4500-N$_{org}$	28 days Cool 4EC Plastic or glass container	Total Kjeldahl nitrogen is the sum of organic and ammonia nitrogen in a sample. Sample digestion and distillation are required and are included or referenced in the method.
Ammonia Nitrogen (NH_3-N)	SM-4500-NH_3	28 days Cool 4EC Plastic or glass container	All samples must be distilled using procedure SM-4500-NH_3 B prior to analysis by one of the specific analysis procedures listed.
Nitrite Nitrogen (NO_2-N)	SM-4500-NO_2^-	48 hours Cool 4EC Plastic or glass container	Nitrite nitrogen is an intermediate oxidation state of nitrogen and can be converted by bacteria to NO_3^- or NH_3. Analyze within holding time to prevent this conversion.
Nitrate Nitrogen (NO_3-N)	SM-4500-NO_3^- SW-846 Method 9056 SW-846 Method 9210	28 days Cool 4EC Plastic or glass container	Nitrate nitrogen is the fully oxidized state of nitrogen. Organics may interfere with the method.
Organochlorine Pesticides	Analysis procedures SW-846 Method 8081A Extraction procedure, SW-846 Method 3540C/3550B (Method used is dependent on acceptable detection limits.)	14 days from collection to sample extraction. Cool 4EC Amber glass jar	The pesticides are bioaccumulative, stable and toxic. Phthalate esters can pose a major interference problem when using an EC detector.
PCBs	Analysis procedures SW-846 Method 8082	14 days from collection to sample extraction.	The PCBs are bioaccumulative, stable and toxic. Phthalate esters can pose a major interference problem when using

Pollutant	Analysis Method Description	Maximum Holding Time Sample Preservation Sample Container	Comments
	Extraction procedure, SW-846 Method 3540C/3550B (Method used is dependent on acceptable detection limits.)	Cool 4EC Amber glass jar	an EC detector.
Semivolatile Organics	Analysis procedure, SW-846 Method 8270C Extraction procedure, SW-846 Method 3540C/3550B (Method used is dependent on acceptable detection limits.) Possible extract cleanup procedures include: SW-846 3610B, 3620B, 3630C, 3640A, 3650B, and 3660B (Cleanup method used is dependent on expected interferences)	14 days from collection to sample extraction. Cool 4EC Amber glass jar with Teflon liner.	Method is used to quantify most B/N/A organic compounds that are soluble in methylene chloride. Such compounds include polynuclear aromatic hydrocarbons, phthalate esters, ketones, anilines, pyridines, quinolines, aromatic nitro compounds and phenols.
Volatile Organics	Analysis procedure, SW-846 Method 8260B Purge-and-trap sample preparation procedure, Method 5035	14 days from collection. Cool 4EC Glass jar with Teflon liner.	Method is used to quantify most volatile organic compounds that have boiling points below 200EC and are insoluble or slightly soluble in water. Such compounds include low-molecular-weight halogenated hydrocarbons, aromatics, ketones, nitriles, acetates, acrylates, ethers, and sulfides. The laboratory where volatile analysis is performed should be completely free of solvents. Effective use of Method 8260 requires use of preparative Method 5035, which involves a closed-system purge-and-trap device and has sample collection procedures and containers specific to that preparative method.

Pollutant	Analysis Method Description	Maximum Holding Time Sample Preservation Sample Container	Comments
Other			By request

REFERENCES:

SM**C***Standard Methods For The Examination of Water and Wastewater*, 18th Edition. American Public Health Association, Washington, DC. 1992.

SW**C**Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846), 3rd Ed., Update III. EPA, December 1996.

ASTM**C***Standard Practice for Recovery of Viruses from Wastewater Sludge*. Annual Book of ASTM Standards: Section 11, Water and Environmental Technology, 1992.

Kenner**C**Kenner, B.A. and H.P. Clark. *Detection and Enumeration of Salmonella and Pseudomonas aeruginosa*. J. Water Pollution Control Federation, 46(9): 2163-2171, 1974.

Sparks**C**Sparks, D.L., Editor. *Methods of Soil Analysis: Part 3, Chemical Methods.* 1996 Soil Science Society of America, Inc., Madison, WI, U.S.A.

Yanko**C**Yanko, W.A. *Occurrence of Pathogens in Distribution and Marketing of Municipal Sludges*. EPA 600/1-87-014, 1987. NTIS PB 88-154273/AS

SECTION 2.2 C ANALYTICAL METHODS FOR ORGANIC POLLUTANTS IN BIOSOLIDS

Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (EPA Publication SW-846, Third Ed.) is the source for EPA-approved analytical methods to determine the concentrations of many constituents of solid and hazardous wastes. These methods also have been approved for other purposes, for example, determining pollutant concentrations in biosolids destined for land application or surface disposal.

Many of the SW-846 methods for analyzing organic compounds may be unfamiliar to POTW operators, since neither NPDES nor the sludge use and disposal standards (40 CFR Part 503) requires these analyses to be performed on biosolids or wastewater. In recent years, testing of biosolids for organic pollutants has become more common. Operators who are performing groundwater monitoring under the requirements of the Resource Conservation and Recovery Act (RCRA), or who have been required in the past to characterize their biosolidss for land disposal, may have previously encountered these analytical methods.

As noted earlier, the SW-846 manual is published by the EPA Office of Solid Waste (OSW) and is intended to be a "living document," in that it is updated with some regularity to include new analytical methods for existing analytes, methods for new analytes, and revisions to existing methods that are designed to improve data quality and address difficult sample types. It is OSW's intent that the latest version of a given method be used whenever specified in a Resource Conservation and Recovery Act (RCRA) regulation. Method revisions are indicated by the addition of a letter suffix to the method number, e.g., Method 8270C is the third revision of the original Method 8270.

This article will provide an introduction to three of the most common SW-846 methods for analyzing organic compounds, so that operators who use these methods can better understand their advantages, disadvantages, and limitations. A specific method for determining organic lead compounds also is presented. **Although three analytical methods are discussed objectively, Region VIII allows for the use of SW-846 Methods 8270C and 8260B for measuring organic pollutants in biosolids. Method 8015 and all modifications are not to be used. Method 8015 lacks specificity (both in number of analytes and identification) and yields many false positives as well as negatives, for organic contaminants and organic matter matrices, such as biosolids.**

The SW-846 "8000" Series Methods

The SW-846 manual is designed in a modular format, with separate procedures for sample preparation, cleanup, and determinative analyses. Most sample analyses will include at least a preparative procedure and a determinative analysis. The analysis of biosolids will often benefit from the use of one or more of the cleanup methods. Some samples simply cannot be adequately analyzed without the use of the cleanup methods. While is it common to discuss SW-846 analyses by only referring to the number of the determinative method, a thorough specification of the actual procedures will mean also stating the preparative method and any cleanup procedures that may be needed.

The different types of procedures are grouped into numbered series of methods. The determinative methods for organic compounds all fall into the 8000 Series methods. Method 8000B is the so-called "base method" for the series, and describes many of the common terms, quality control operations, and provides background information on many basic chromatographic techniques. Method 8000 does not actually involve any target compounds. It is simply a reference that applies to all of the various chromatographic procedures.

Most of the procedures for organic compounds use a gas chromatograph (GC) to separate, identify, and quantify organic pollutants. Any of these methods can be used on aqueous, semisolid, or solid samples. Contaminants are either extracted from the samples with an organic solvent prior to analysis or purged from the sample directly into the instrument. SW-846 contains a variety of extraction procedures that may be applied to sample matrices. Those extraction procedures are found in the 3500 Series of methods, while the procedures for introducing volatile contaminants are found in the 5000 Series of methods. The cleanup methods are all found in the 3600 Series.

Associated with each determinative method is a "target compound list" (TCL), the list of compounds which EPA has determined can be analyzed satisfactorily in various physical forms by each method. There are two *critical* points to consider when selecting a determinative method.

- Some chemicals may be target compounds for more than one method. You may need to find the method with the most appropriate selectivity and sensitivity for you needs.

- Some of the SW-846 methods list well over 100 hundred compounds that *can* be determined using the method. The fact that a compound is listed as a target compound in a given SW-846 method does *not* imply that there is a regulatory need to perform an analysis for that compound, under either the RCRA regulations or 40 CFR 503. Some methods even point out that not all of the compounds can be determined from a single instrumental analysis. A common mistake is to call a laboratory ask for a price quote on "Method XXXX" when what you may really need is the analysis of the sample for a specific set of compounds, for example, polycyclic aromatic hydrocarbons (PAHs). Asking for the analysis of all the compounds not only adds to the cost of the analysis, it makes it more likely that the results for one or more compounds will fail to meet all of the quality control requirements in the method. Such failures may lead to questions about the results for the analysis, even if the compound was not important to the specific project.

A GC works on the principle that organic compounds will migrate through an adsorbent material at different rates, depending on the temperature and physical and chemical characteristics of the compounds and adsorbent. In practice, a sample (or sample extract) is vaporized at about 550EF (290EC), and the vapors are swept through a long column of adsorbent by a carrier gas. The adsorbent column is kept heated inside an oven to prevent the sample vapors from condensing in the column. The sample constituents are separated as they pass through the column, so that each constituent emerges from the column as a discrete "slug" or band. Depending on the analytical method, these bands can then be measured by various detectors to identify and quantify each compound. Each method uses different detectors, which may be more or less sensitive to certain types of compounds; thus, certain methods can be used to detect extremely low concentrations of specific chemicals, even in the presence of large amounts of other compounds.

Constituent concentrations are determined by comparing each band in a sample with the results obtained by analyzing standard solutions containing known concentrations of each compound. Normally, three to five standards containing varying constituent concentrations are used to establish the working range of the instrument. Standard concentrations are chosen so that detector response will be linear within the working range, and so that the range will encompass the concentrations expected to be found in environmental samples. Samples, or sample extracts, above the calibration range of the instrument must be diluted to bring the results within the range and reanalyzed. Samples with results below the range may be reported as less than the lower limit of the calibration range, or an estimate of the concentration may be made by assuming that the calibration is linear between the lowest standard and a theoretical zero concentration standard. If such as estimate is made, the results are usually marked with a "flag" by the laboratory to indicate the increased uncertainty in the value.

Many different types of detectors can be used with a GC. The methods discussed here use either a mass spectrometer (MS, used in Methods 8260B and 8270C) or a flame ionization detector (FID, used in Method 8015B). With a FID, the effluent vapors from the adsorbent column are passed through a hydrogen flame. As each band passes through the flame, the constituent compounds are ionized (given an electrical charge). These charged particles produce an electrical current which can be detected and measured.

A MS identifies chemical structures by ionizing the constituents in the column effluent with a beam of high energy electrons. The stream of charged particles then is passed through a magnetic field, which causes the particles' path to curve. When the charged particles eventually collide with the inside wall of the detector, an electrical current again is produced which can be detected and measured. Since heavy particles are more difficult to deflect than light particles, the heavier particles will strike the detector at a distance farther from the entrance to the detector. By accurately measuring these path lengths, the mass (and thus the exact chemical composition) of each particle can be determined. In addition, most charged particles show a characteristic tendency to fragment as they move through the magnetic field; this fragmentation is detected when several particles with different masses strike the detector simultaneously. The fragmentation pattern is highly dependent on the chemical composition of the original particle, so the patterns can be used as "fingerprints" to precisely identify large numbers of different chemicals.

These GC methods will work only with samples containing constituents which can be vaporized at relatively low temperatures, and which are thermally stable (will not decompose at the GC operating temperatures).

Methods 8260B, 8270C, and 8015B

SW-846 Methods 8260B, 8270C, and 8015B are three of the most commonly used GC methods for analyzing organic pollutants in solid and hazardous wastes. Together, Methods 8260B and 8270C will detect most of the organic chemicals which currently form the basis for listing certain waste streams as hazardous (the "F"- and "K"-listed wastes found in 40 CFR 261.31 and 261.32), or for declaring a non-listed waste as exhibiting the toxicity characteristic (40 CFR 261.24). The majority of these compounds are either solvents (chlorinated or hydrocarbon-based) and other industrial chemicals, or PAHs, which are found in petroleum products or are formed during combustion of organic materials. Some of these solvents, PAHs, and other chemicals are known or suspected carcinogens (cancer-causing agents).

Method 8015 originally was designed to detect low levels of six nonhalogenated organic compounds that were not easily analyzed using the GC/MS methods available at that time. Over the years, various laboratories and state regulatory authorities modified Method 8015 to address other target compounds, including gasoline and diesel fuels. The result was a series of procedures that were commonly referred to as "modified Method 8015." Unfortunately, depending on the source, one modification might not resemble another. In 1996, OSW revised the method to its current version, 8015B, and included procedures to specifically address the analyses of gasoline-range organics (GRO) and diesel-range organics (DRO), as well as a total of 27 specific nonhalogenated organics.

None of these three methods was designed as a preferred method to analyze pesticides or herbicides (although some pesticides and herbicides may be identified by Method 8270C).

Table 2.2-1 summarizes the key features of these methods; each method is discussed in more detail below.

Table 2.2-1. Summary of Features of SW-846 Methods 8260B, 8270C, and 8015B

SW-846 Method	Instrument and Detector	Chemicals detected (Note 1)	Non-target compounds identified?	Relative cost of analyses (Note 2)
8260B	GC/MS	Volatile organics	Yes (Note 3)	Moderately expensive
8270C	GC/MS	Semivolatile organics	Yes (Note 3)	Most expensive
8015B	GC/FID	Nonhalogenated volatiles organics, plus gasoline-range organics and diesel-range organics (Note 4)	No	Least expensive

Note 1: See Tables 2.2-2, 2.2-3, and 2.2-4 for specific target compounds for each method.

Note 2: Prices vary widely among laboratories, and also can depend on the target compounds to be analyzed. (For example, analyzing for both gasoline and diesel by Method 8015B will cost more than if only one of these fractions is determined.) Operators should solicit price quotes from several laboratories, if possible, and should discuss their analytical requirements with the laboratories' customer service representatives before agreeing to contractual arrangements.

Note 3: Compounds not on the target compounds list can be determined by a search of a mass spectral library. The resulting identifications are tentative, since an authentic standard of the compound is not also analyzed. The results for the tentatively identified compounds (TICs) are NOT quantitative. They are gross estimates of the relative magnitude of the concentration. Analytical costs are higher if TICs are determined in addition to TCL constituents.

Note 4: Petroleum hydrocarbons such as GRO and DRO can be measured by Method 8015B.

Table 2.2-2 Volatile Organic Compounds Detected by Method 8260B.

Compound	Sensitivity (parts per billion) *
Acetone	100
Benzene	5
Bromodichloromethane	5
Bromoform	5
Bromomethane	10
2-Butanone (methyl ethyl ketone; MEK)	100
Carbon disulfide	5
Carbon tetrachloride	5
Chlorobenzene	5
Chlorodibromomethane	5
Chloroethane	10
2-Chloroethyl vinyl ether	10
Chloroform	5
Chloromethane	10
1,1-Dichloroethane	5
1,2-Dichloroethane	5
1,1-Dichloroethene	5
trans-1,2-Dichloroethene	5
1,2--Dichloropropane	5
cis-1,3-Dichloropropene	5
trans-1,3-Dichloropropene	5
Ethylbenzene	5
2-Hexanone	50
Methylene chloride (dichloromethane)	5
4-Methyl-2-pentanone (methyl isobutyl ketone; MIBK)	50
Styrene	5
1,1,2,2-Tetrachloroethane	5
Tetrachloroethene (perchloroethylene; "perc")	5
Toluene	5
1,1,1-Trichloroethane	5
1,1,2-Trichloroethane	5
Trichloroethene	5
Vinyl acetate	50
Vinyl chloride	10
Xylene (Total)	5

* Sensitivity (detection limits) for these compounds in biosolids containing about 20% solids should be no greater than 1 mg/kg (dry weight basis).

Table 2.2-3 Semivolatile Organic Compounds Detected by Method 8270C

Compound	Sensitivity (parts per billion) for liquid samples *	Compound	Sensitivity (parts per billion) for liquid samples *
Acenapthene	10	Dimethyl phthalate	10
Acenaphthylene	10	4,6-Dinitro-2-methylphenol	50
Anthracene	10	2,4-Dinitrophenol	50
Benz(a)anthracene	10	2,4-Dinitrotoluene	10
Benzo(b)fluoranthene	10	2,6-Dinitrotoluene	10
Benzo(k)fluoranthene	10	Di-n-octyl phthalate	10
Benzo(ghi)perylene	10	Fluoranthene	10
Benzo(a)pyrene	10	Fluorene	10
Benzoic acid	50	Hexachlorobenzene	10
Benzyl alcohol	20	Hexachlorobutadiene	10
Bis(2-chloroethoxy)methane	10	Hexachlorocyclopentadiene	10
Bis(2-chloroethyl) ether	10	Hexachloroethane	10
Bis(2-chloroisopropyl) ether	10	Indeno(1,2,3-cd)pyrene	10
Bis(2-ethylhexyl) phthalate	10	Isophorone	10
4-Bromophenyl phenyl ether	10	2-Methylnaphthalene	10
Butyl benzyl phthalate	10	2-Methylphenol	10
4-Chloroaniline	20	4-Methylphenol	10
4-Choro-3-methylphenol	20	Naphthalene	10
2-Chloronaphthalene	10	2-Nitroaniline	50
2-Chlorophenol	10	3-Nitroaniline	50
4-Chlorophenyl phenyl ether	10	4-Nitroaniline	50
Chrysene	10	Nitrobenzene	10
Dibenz(a,h)anthracene	10	2-Nitrophenol	10
Dibenzofuran	10	4-Nitrophenol	50
Di-n-butyl phthalate	10	N-Nitrosodiphenylamine	10
1,2-Dichlorobenzene	10	N-Nitroso-di-n-propylamine	10
1,3-Dichlorobenzene	10	Pentachlorophenol	50
1,4-Dichlorobenzene	10	Phenanthrene	10
3,3'-Dichlorobenzidine	20	Phenol	10
2,4-Dichlorophenol	10	Pyrene	10
2,6-Dichlorophenol	10	1,2,4-Trichlorobenzene	10
Diethyl phthalate	10	2,4,5-Trichlorophenol	10
2,4-Dimethylphenol	10	2,4,6-Trichlorophenol	10

* Sensitivity (detection limits) for these compounds in dewatered biosolids, soils, or other solid and semisolid samples are approximately 30 times higher than the levels shown here for liquid samples. Sensitivity in biosolids containing about 20% solids should be no greater than 1 mg/kg (dry weight basis).

Table 2.2-4 Organic Compounds Detected by Method 8015B

Specific compounds detected by Method 8015B	
Acetone	Isobutyl alcohol (2-Methyl-1-propanol)
Acetonitrile	Isopropyl alcohol (2-Propanol)
Acrolein	Methanol
Acrylonitrile	Methyl ethyl ketone (MEK, 2-Butanone)
Allyl alcohol	Methyl isobutyl ketone (MIBK, 4-Methyl-2-pentanone)
1-Butanol (*n*-Butyl alcohol)	*N*-Nitroso-di-*n*-butylamine
t-Butyl alcohol (2-Methyl-2-propanol)	Paraldehyde
Crotonaldehyde	2-Pentanone
Diethyl ether	2-Picoline
1,4-Dioxane	1-Propanol (*n*-Propyl alcohol)
Ethanol	Propionitrile
Ethyl acetate	Pyridine
Ethylene glycol	*o*-Toluidine
Ethylene oxide	
Petroleum Hydrocarbon fractions addressed in Method 8015B	
Gasoline-range organics (GRO, C_6 to C_{10})	Diesel-range organics (DRO C_{10} to C_{28})

Method 8260B

Method 8260B is used to analyze the volatile organic compounds (VOCs; compounds with boiling points less than approximately 300EF [150EC]) shown in Table 2.2-2. Method 8260 replaces the earlier Method 8240, which was deleted from the SW-846 manual in 1996, as it employed an outdated technique, packed GC columns. Method 8260 employs a capillary GC column which can separate a wider range of organic compounds.

Many laboratories also may be able to analyze additional chemicals by this method; ask your customer service representative about the laboratory's specific TCL. As noted earlier, the presence of a compound on the TCL does not imply a regulatory requirement for its analysis. Therefore, talk with the laboratory to ensure that their TCL includes all of the constituents you require for analysis.

As shown in Table 2.2-1, Method 8260 uses a GC/MS combination. VOCs are removed from a sample by bubbling purified nitrogen or helium through it (solid samples are initially slurried in water or a methanol-water mixture); the stripped or "purged" compounds are "trapped" in a small column of adsorbent (thus the name "purge-and-trap" given to this technique for isolating VOCs from the sample). The VOCs are desorbed from the trap by rapidly heating the adsorbent and then passed through the analytical column as described previously.

Method 8270C

Method 8270C is used to detect the semivolatile organic compounds (SVOCs; compounds with boiling points between about 300°F [150°C] and 850°F [450°C]) shown in Table 2.2-3. As with Method 8260, Method 8270 also uses GC/MS (see Table 2.2-1). SVOCs are extracted from a solid or liquid sample with a water-insoluble organic solvent (methylene chloride). In the case of water samples, different compounds can be extracted preferentially by adjusting the sample to a high (alkaline) pH or a low (acidic) pH before extraction. (Solid samples do not undergo pH adjustment before extraction.) The combined solvent extracts are then concentrated to a small volume and analyzed as described above.

Method 8015B

Method 8015 originally was designed to detect low levels of six nonhalogenated organic compounds that were not easily analyzed using the GC/MS methods available at that time. Over the years, various laboratories and state regulatory authorities modified Method 8015 to address other target compounds, including gasoline and diesel fuels, and the somewhat confusing term "total petroleum hydrocarbons" or "TPH." The result was a series of procedures that were commonly referred to as "modified Method 8015." Unfortunately, depending on the source, one modification might not resemble another.

Petroleum hydrocarbons are not regulated under the various RCRA statutes governing hazardous wastes, but rather under the regulations governing releases from underground storage tanks (40 CFR Part 280). In 1996. OSW revised the method to its current version, 8015B, and included procedures to specifically address the analyses of gasoline-range organics (GRO) and diesel-range organics (DRO), as well as a total of 27 specific nonhalogenated organics. OSW's goal was to eliminate the confusion surrounding the many versions of "modified Method 8105." The procedures for GRO and DRO are based on methods developed by the petroleum industry and address the particular difficulties of petroleum spill analyses. However, the GRO and DRO analyses need not be conducted as part of the analysis of the original nonhalogenated volatiles. Whatever list of target compounds is used for Method 8015B, the analysis must include some sample preparation technique. For the analysis of biosolids, purge-and-trap is the most likely sample preparative technique, although solvent extraction is used for DRO analyses.

Some states may still retain their modified versions of Method 8015 for specific uses. Given the historical confusion surrounding petroleum hydrocarbon analyses in general, it is best to check with the laboratory to determine how and why they perform analyses using Method 8015.

California Method for Determining Organic Lead Compounds

In October 1989, the California Department of Health Services (DHS) published the "Leaking Underground Fuel Tank Field Manual: Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure." This manual contains detailed methods for determining TPH by GC/FID (the "California modification" to Method 8015) and organic lead compounds. Organic lead compounds formerly were widely used as gasoline antiknock additives, and large amounts of these compounds are now found in petroleum sludges.

In the California DHS organic lead method, a sample is extracted with organic solvent to isolate the organic lead compounds; other forms of lead (inorganic lead) are not removed by extraction. The extract then is analyzed by an atomic absorption (AA) spectrometer, using SW-846 Method 7420 or 7421, to determine the organic lead concentration.

Advantages, Disadvantages, and Limitations

As with any analytical procedure, each of these methods has certain advantages, disadvantages, and limitations, as shown below. Study the following lists carefully before deciding whether the method is appropriate for your particular needs. One limitation shared by all of these methods is that permit conditions or other regulatory requirements may require the use of a different analytical method, even if one of these methods seems to be appropriate. Check with your state or regional EPA regulator, technical contact, or your laboratory's customer service representative to make sure the correct analytical method is being used.

METHOD 8260: VOLATILE ORGANICS BY GC/MS USING PURGE-AND-TRAP

Advantages

Availability **C** Virtually all laboratories performing VOC analyses have equipment and personnel dedicated to performing Method 8260 and related GC/MS procedures.

Widespread use **C** Many thousands of analyses have been performed using this method over the years; the accuracy and precision of the method are well known. Results from different analyses can be readily compared to one another.

Applicability **C** The method can be used on any sample matrix (surface water, groundwater, wastewater, soils, sediments, or sludges).

Sensitivity **C** Most target compounds can be measured accurately down to 5 or 10 parts per billion (ppb), and estimated concentrations can be obtained down to 1 or 2 ppb. However, other methods may be more sensitive for certain specific pollutants (such as benzene or chlorinated solvents such as trichloroethene).

Specificity **C** Target compound identification is based on both the retention time of the compound on the adsorbent column, and the mass spectral pattern of the constituent; both of these criteria must match the characteristics of the standard reference material before positive identification can be made. Accurate concentration measurements usually can be made in the presence of interfering compounds.

Types of compounds analyzed **C** At additional cost, up to 10 non-target compounds in each sample may be tentatively identified. Subsequent confirmation of these tentatively identified compounds (TICs) can suggest or pinpoint a previously unsuspected source of contamination.

Disadvantages and Limitations

Cost **C** Most laboratories will charge approximately $200 for each sample. Analytical costs generally will be lower if only a certain standard subset of the full TCL is analyzed **C** for example, only those constituents covered by the TCLP toxicity characteristic rule.

Unnecessary detail **C** Since the method was designed to measure a wide range of compounds (most of which are never found in samples from any given source), a large number of irrelevant compounds will be reported as "not detected." The occasional truly significant results tend to become lost in this mass of unnecessary information. If determination of a group of related compounds (such as gasoline constituents) is desired, other methods may be more appropriate. Alternatively, you can request that only certain target compounds be reported.

Types of compounds analyzed **C** Many water-soluble compounds (such as some alcohols, organic acids, and amines), and compounds which do not emerge from the adsorbent column as a sharp band, cannot be analyzed effectively.

Speed **C** Due to stringent method requirements for calibrating the analytical instruments, fewer samples per day can be analyzed than by other methods. (This is seldom a concern, unless a laboratory is faced with analyzing a large number of samples within a certain holding time deadline.)

METHOD 8270: SEMIVOLATILE ORGANICS BY GC/MS USING CAPILLARY COLUMN

Advantages

Availability C Virtually all laboratories performing SVOC analyses have equipment and personnel dedicated to performing Method 8270 and related GC/MS procedures.

Widespread use C Many thousands of analyses have been performed using this method over the years; the accuracy and precision of the method are well known. Results from different analyses can be readily compared to one another.

Applicability C The method can be used on any sample matrix (surface water, groundwater, wastewater, soils, sediments, or sludges).

Sensitivity C Most target compounds can be measured accurately down to between 10 and 50 ppb in water, and estimated concentrations can be obtained down to about 5 ppb. Limits for other matrices, such as sludge, are somewhat higher. Other methods may be more sensitive toward certain specific pollutants.

Specificity C Target compound identification is based on both the retention time of the compound on the adsorbent column, and the mass spectral pattern of the constituent; both of these criteria must match the characteristics of the standard reference material before positive identification can be made. Accurate concentration measurements usually can be made in the presence of interfering compounds.

Types of compounds analyzed C At additional cost, up to 20 non-target compounds in each sample may be tentatively identified. Subsequent confirmation of these tentatively identified compounds (TICs) can suggest or pinpoint a previously unsuspected source of contamination.

Disadvantages and Limitations

Cost C Method 8270 is the single most expensive commonly-used analytical method. Most laboratories will charge between $400 and $600 for each sample. Analytical costs generally will be lower if only a certain standard subset of the full TCL is analyzed C for example, only those constituents covered by the TCLP toxicity characteristic rule, or only acid-extractable compounds.

Unnecessary detail C Since the method was designed to measure a wide range of compounds (most of which are never found in samples from any given source), a large number of irrelevant compounds will be reported as "not detected." The occasional truly significant results tend to become lost in this mass of unnecessary information. If determination of a group of related compounds (such as petroleum constituents) is desired, other methods may be more appropriate. Alternatively, you can request that only certain target compounds be reported.

Types of compounds analyzed C Many non-target SVOCs decompose at temperatures below their boiling points, and thus cannot pass through the GC column. Most phenols are sufficiently soluble in water that they are not extracted efficiently, and results for these compounds may be biased low. Several of the target compounds shown in Table 2.2-3 exhibit erratic behavior, and can be difficult to analyze.

Speed C Due to stringent method requirements for calibrating the analytical instruments, fewer samples per day can be analyzed than by other methods. (This is seldom a concern, unless a laboratory is faced with analyzing a large number of samples within a certain holding time deadline.)

METHOD 8015: NONHALOGENATED VOLATILE ORGANICS USING GC/FID

Advantages

Cost **C** This method is one of the least expensive for analyzing organic compounds, and this is its major advantage when large numbers of samples must be analyzed. Most laboratories will charge around $100 per sample for each fraction (purgeable and extractable; prices as of July 1994).

Availability **C** Virtually all laboratories performing VOC analyses have equipment and personnel dedicated to performing Method 8015.

Speed **C** Samples usually can be analyzed more quickly than by GC/MS methods. (This is seldom a concern, unless a laboratory is faced with analyzing a large number of samples within a certain holding time deadline.)

Simplicity **C** Analytical reports are easy to read, since results for only one or a few target constituents (acetone, gasoline, diesel, etc.) are reported.

Types of compounds analyzed **C** This method addresses 27 specific organic compounds, mostly alcohols, ketones, and aldehydes, as well as two specific ranges of petroleum hydrocarbons, gasoline-range organics (GRO) and diesel-range organics (DRO).

Disadvantages and Limitations

Accuracy **C** The accuracy for the individual compounds is generally good, and comparable to the GC/MS methods. Petroleum products are complex mixtures containing a few dozen to several hundred individual chemicals. The GRO and DRO are determined by summing the instrument responses between different sets of marker compounds (2-methylpentane and 1,2,4-trimethylpentane for GRO; the alkanes C_{10} and C_{28} for DRO). When properly performed, both determinations are accurate.

"Weathering" (preferential removal of certain chemicals from environmental samples) also can complicate component identification and measurement.

Sensitivity **C** The sensitivity of GC/FID is generally as good or better than that of GC/MS. *However,* the individual target compounds for Method 8015 are much more soluble in water that the target compounds in most GC/MS methods. Their high water-solubility makes then much more difficult to purge or extract from water or wet samples such as biosolids. Thus, when using purge-and-trap and the sample introduction technique, the sensitivity of Method 8015 for the target compounds can be lower than the sensitivity of GC/MS for other compounds. The two petroleum fractions (GRO and DRO) generally can be measured accurately down to about 1 to 5 parts per million (ppm) (1000 - 5000 ppb).

Specificity **C** Target compound identification is based only on the retention time of the compound on the adsorbent column. Interfering compounds that come off the column at the same time can be mistaken for one of the target compounds, resulting in false positives or results biased high. This problem usually can be overcome by reanalyzing the sample (at additional cost), using a column containing a different adsorbent material to confirm the primary results; however, this largely negates the method's speed and cost advantages. The analyses of GRO and DRO require more skill on the part of the analyst than the analysis of the individual compounds in the method.

METHOD 8015: NONHALOGENATED VOLATILE ORGANICS USING GC/FID
(Continued)

Advantages

Types of compounds analyzed **C** Only those compounds for which the instrument was calibrated can be measured. Unknown constituents cannot be identified by this method.

CALIFORNIA DHS METHOD FOR ORGANIC LEAD:

Advantage

Specificity **C** This method measures total organic lead compounds in the presence of other types of lead compounds. This is considered important, since organic lead is thought to be much more toxic than other forms.

Disadvantages and Limitations

Sensitivity **C** Organic lead can be measured accurately only down to 100 to 500 ppb. This level is about 10 to 100 times higher than the sensitivity for total lead which can be obtained by other methods.

Availability **C** Since this method was developed by the California Department of Health Services, it may not be widely known outside California. Most laboratories likely will not perform this method unless they are certified by the California DHS.

Cost **C** Analytical cost is around $50 per sample (prices as of July 1994). This cost is somewhat higher than other methods for determining total lead.

For these reasons, Method 8015 often is used as an inexpensive screening method to detect the possible presence of petroleum contamination, which then can be confirmed by duplicate analyses using a different GC column or different methods. If you are looking for particular contaminants in a biosolids sample, always use the analytical methods that will specifically measure those contaminants.

As a result, EPA Region 8 does not recommend the use of Method 8015 for organic analysis of biosolids.

SECTION 2.3 C TOXICITY, BIOSOLIDS, AND THE TCLP TEST

The Toxicity Characteristic Leaching Procedure (TCLP) is a testing procedure developed by the EPA Office of Solid Waste (OSW). It is used for determining whether solid wastes, including domestic biosolids, exhibit the regulatory characteristic of "toxicity" (40 CFR 261) and therefore must be handled as hazardous waste. The leaching procedure described in Method 1311 uses a dilute acetic solution to model the movement of contaminants from a block of waste material placed in an unlined municipal landfill into the underlying groundwater.

The sample is leached using Method 1311, and then the liquid leachate is analyzed using the sample preparation procedures applied to other aqueous samples, e.g., acid digestion procedures for metals, purge-and-trap procedures for volatiles, and solvent extraction procedures for semivolatile organics, pesticides, and PCBs.

Following the TCLP analysis, the concentrations of 44 specific pollutants are compared to the Toxicity Characteristic (TC) regulatory levels. If the concentration of pollutants in the TCLP extract meet or exceed these regulatory levels, then the sample exhibits the RCRA characteristic of toxicity and the waste is classified as hazardous. If the biosolids leachate fails the TC, then land application is not allowed. Table 2.3-1 presents the analytical classification and limits for TCLP constituents.

Table 2.3-2 presents the results of studies which were conducted in 1985-86 by the OSW. The studies were used to determine if the TCLP and TC regulatory limits would cause municipal sewage biosolids to be classified as a hazardous waste. The Association of Metropolitan Sewerage Agencies (AMSA) and the OSW analyzed split samples from 12 POTWs using identical analytical methodology.

None of the biosolids tested by the laboratories had TCLP extract concentrations that exceeded the proposed TC regulatory levels. For most contaminants, except metals, there were non-detects in the TCLP extracts and very few contaminants were detected by either laboratory on the same biosolids sample. The importance to POTW operators is two-fold. First, TCLP information may be helpful when establishing a public education program. Uninformed citizens may think that biosolids are hazardous by nature and a threat to human health and the environment. The results of this study indicate otherwise. Second, the 12 POTWs involved in the study were in urbanized areas and accepted from 5% to 90% of their flows from industrial sources. It is quite likely that biosolids from small and medium size POTWs would produce TCLP extract concentrations lower than the biosolids analyzed in the study, and thus have a better chance of passing the TCLP test.

Table 2.3-1. Analytical Classification and Limits for TCLP Constituents.

Constituent	Limit, mg/L
Pesticides	
Chlordane	0.03
Endrin	0.02
Heptachlor	0.008
Lindane	0.4
Methoxychlor	10.0
Toxaphene	0.5
Herbicides	
2,4-D	10.0
2,4-5-TP Silvex	1.0
Volatiles	
Benzene	0.5
Carbon tetrachloride	0.5
Chlorobenzene	100.0
Chloroform	6.0
1,2-Dichloroethane	0.5
1,1-Dichloroethylene	0.7
Methyl ethyl ketone	200.0
Tetrachloroethylene	0.7
Toluene	1000.0
Trichloroethylene	0.5
Vinyl chloride	0.2
Semivolatiles	
o-Cresol	200.0
m-Cresol	200.0
p-Cresol	200.0
1,2-Dichlorobenzene	300.0
1,4-Dichlorobenzene	7.5
2,4-Dinitrotoluene	0.1
Hexachlorobenzene	0.02
Hexachlorobutadiene	0.5
Hexachloroethane	3.0
Nitrobenzene	2.0
Pentachlorophenol	1.0
2,4,5-Trichlorophenol	400.0
2,4,6-Trichlorophenol	2.0
Metals	
Arsenic	5.000
Barium	100.0
Cadmium	1.0
Chromium	5.0
Lead	5.0

Constituent	Limit, mg/L
Mercury	0.2
Selenium	1.0
Silver	5.0

Note that the units for the Toxicity Characteristic are given in mg/L, as they are judged from the results of the analysis of the aqueous leachate itself, not the original solid sample.

Table 2.3-2 Characteristics of the 12 POTW's and Their Biosolids in the 1986 EPA-AMSA TCLP and Compositional Test Series.

POTW	Daily Flow (MGD)	% Industry	Type of Wastewater Treatment	Biosolids Parameters				
				Type of Treatment	Sample Point	pH	% Water	Pass/Fail
A	30-60	50	Primary and Waste Activated	No Digestion, Lime and Ferric Vacuum Filters	Filters, Composite Cake	12.2	79	Pass
B	100-150	35	Waste Activated	No Digestion, Ferric Vacuum Filters	Conveyor from Filter Discharge	5.8	83	Pass
C	>600	30	Primary and Waste Activated	Anaerobic Digestion	Draw Off from Digester	7.4	95	Pass
D	4-10	90	Waste Activated Extended Air	Aerobic Digestion (60 Days), Belt Filter Press	Conveyor from Filter Discharge	6.3	81	Pass
E	65-100	30	Waste Activated	Anaerobic Digestion, Lime, Vacuum Filters	Vacuum Filter Cake before Lime	4.6	82	Pass
F	70-100	40	Primary and Pure Oxygen	Anaerobic Digestion, Polymer, Centrifuged	Conveyor from Filter Discharge	7.8	82	Pass
G	>600	30-40	Primary and Waste Activated	No Digestion, Polymer Belt, Filter Press	Filter	7.0	77	Pass
H	40-60	25	Waste Activated	No Digestion, Lime and Ferric, Vacuum Filter	Storage	10.7	78	Pass
I	275-325	5	Waste Activated	Anaerobic Digestion	Bottom Ash	6.4	96	Pass
J	125-175	40	Primary	Polymer, Vacuum Filter, Incineration	Conveyor from Filter Discharge	8.3	0	Pass
K	80-120	55	Primary and Waste Activated Pure Oxygen	Low Pressure Oxidation-zimpro, Vacuum Filter	Storage	5.6	66	Pass
L	80-100	50	Waste Activated	Anaerobic Digestion, Polymer, Belt Filter Press	Unknown	6.6	70	Pass

SECTION 2.4 C BIOSOLIDS SAMPLING GUIDANCE FOR PUBLICLY OWNED TREATMENT WORKS

This reference sheet provides specific guidance to POTW operators on sampling considerations associated with short- and long-term biosolids storage facilities such as drying beds, storage lagoons, biosolids piles, surface disposal units, and wastewater lagoons. The sampling protocols and requirements presented herein should be considered prior to disposing of biosolids that have been stored in one of the above ways for a period of months. It is not intended for biosolids generating facilities that dispose of biosolids on a frequent or continuous basis. Self-monitoring requirements for those POTWs which frequently or continuously dispose of biosolids are presented in 40 CFR 503.16 for land application and 40 CFR 503.26 for surface disposal. If your POTW intends to dispose of biosolids in the future, or currently disposes of biosolids, note that all facilities must notify their EPA Region 180 days prior to land applying or land disposing of all biosolids. The notification must include a biosolids sampling plan and a timetable of all sampling and disposal activities.

The following pages present the policy of EPA Region 8 on the statistical basis for representative sampling and the guidance related to the physical act of sampling.

The following areas of concern should be evaluated when developing a sampling plan:

$ Statistical BasisCDetermine how many discrete samples need to be collected to ensure you have collected a representative sample, and how many analyses are required from that group.

$ Physical SamplingCDetermine which parameters are to be analyzed and what type of sampling equipment will be needed.

I. STATISTICAL BASIS FOR BIOSOLIDS SAMPLING

This sampling strategy relies on statistics to determine the total number of grab samples to be collected and EPA Regional policy to determine how many composite samples must be derived from the grab samples and analyzed. For the purposes of this reference sheet, the statistical formulae used to determine the number of samples to be collected are not presented, but can be obtained from the EPA Region VIII Biosolids Coordinator by asking for "Technical Memo - RS/1094/13/2 - Validity of Statistical Basis for Sludge Sampling," dated August 3, 1994.

A. NUMBER OF SAMPLES TO BE COLLECTED AND ANALYZED

The following number of samples must be collected depending on the design flow of the POTW. Table 2.13-1 presents the number of samples required for POTWs with varying design flows. The table indicates that the number of samples required generally increases as the design flow of the POTW increases. Therefore, a POTW with a design flow of less than 1 MGD must collect 27 discrete samples and composite those samples for one analysis. Conversely, a POTW with a design flow of greater than 100 MGD must collect 84 discrete samples and randomly composite and analyze 12 samples from the total of 84. The number of discrete samples has statistical justification while the number of composite samples is based on Regional policy.

Table 2.4-1 is for POTWs which stockpile biosolids in piles, lagoons, or similar facilities for extended periods of time and therefore dispose of biosolids infrequently. [This guidance is not intended for facilities which dispose of biosolids regularly.] Note that the physical size of the biosolids body does not influence the number of samples to be collected. The number of samples presented in Table 2.13-1 is intended for each individual biosolids body.

Therefore, if you have three individual wastewater lagoons that are to be dredged and the biosolids disposed of, you should collect the required number of samples from each of the three lagoons.

Table 2.4-1. Number of Samples Required.

POTW Design Flow (MGD)	Number of Discrete Samples Collected (N)	Number of Composite Samples Derived from (N) and Analyzed	Equivalent Self-Monitoring Frequency
flow≤1	27	1	1/yr
>1flow≤10	42	4	4/yr
>10flow≤100	48	6	6/yr
flow>100	84	12	12/yr

The number of composite samples required to be collected and analyzed is similar to the self-monitoring frequencies presented in 40 CFR Part 503.16 for continuous biosolids generating facilities. Part 503.16 requires POTWs with biosolids production of less than 290 tons/year to monitor only once per year (1/yr), while POTWs which generate more than 15,000 tons/year, must monitor 12 times per year (12/yr). The number of samples to be composited and analyzed relates to the monitoring frequency presented in Part 503.16 because the POTW must monitor for the equivalent of either once per year (1/yr), once per quarter (4/yr), once every 60 days (6/yr), or monthly (12/yr). Therefore, this procedure mirrors the required monitoring frequency for those POTWs which generate and dispose of biosolids on a continuous basis. The rationale is that large POTWs should be required to monitor their biosolids more closely than smaller POTWs; hence the greater monitoring frequency.

B. DETERMINING SAMPLE LOCATIONS

Once you know how many samples are required to be collected and analyzed, you can use the following procedures to ensure that you collect representative samples from the biosolids body. This can be accomplished using a two-dimensional random sampling method to identify the sample location points. The following four steps describe how to determine sampling point locations:

Step [1] Prepare a small scale diagram of the biosolids body on a 8.5" x 11" sheet of paper.

Step [2] Divide the diagram into 100 equally sized squares. Consecutively assign a number (from 0 to 99) to each of the squares. An example grid pattern is presented in Table 2.4-2. (If possible, simply overlay the grid pattern onto your biosolids body diagram).

Step [3] Using a random number table, select a minimum of N numbers from the random number table provided (remembering that N represents the number of samples required). Note that if your biosolids body does not fill the entire grid (e.g., a circular biosolids pile vs. square grid) more numbers are needed for areas without biosolids in the grid sections described in Step 2. A random number table is presented in Table 2.4-3. To select numbers from the random number table, pick a number anywhere on the random number table and move along a straight line in any direction (maintaining that direction) choosing numbers off the table consecutively while traveling along the straight line. Do not use duplicate numbers. If a duplicate number exists along the straight line, ignore it and choose additional numbers until non-duplicated N random numbers have been chosen. If the end of the table is reached, repeat the process until all the numbers have been chosen.

Step [4] Match all selected random numbers to the numbered squares on your grid pattern of the biosolids body. Samples will be taken from the middle of each identified square as it is laid out over the biosolids body.

2,4,-2

Table 2.4-3. Random Numbers (Blocked Merely for Convenience).

(Source: Introductory Statistics, 4th Edition, John Wiley & Sons, New York, NY, 1985)

39 65 76 45 45	19 90 69 64 61	20 26 36 31 62	38 24 97 14 97	95 06 70 99 00
73 71 23 70 90	65 97 60 12 11	31 56 34 19 19	47 83 75 51 33	30 62 38 20 46
72 20 47 33 84	51 67 47 97 19	98 40 07 17 66	23 05 09 51 80	59 78 11 52 49
75 17 25 69 17	17 95 21 78 58	24 33 45 77 48	69 81 84 09 29	93 22 70 45 80
37 48 79 88 74	63 52 06 34 30	01 31 60 10 27	35 07 79 71 53	28 99 52 01 41
02 89 08 16 94	85 53 83 29 95	56 27 09 24 43	21 78 55 09 82	72 61 88 73 61
87 18 15 70 07	37 79 49 12 38	48 13 93 53 96	41 92 45 71 51	09 18 25 38 94
98 83 71 70 15	89 09 39 59 24	00 06 41 41 20	14 36 59 25 47	54 45 17 24 89
10 08 58 07 04	76 62 16 48 68	58 76 17 14 86	59 53 11 52 21	66 04 18 72 87
47 90 56 37 31	71 82 13 50 41	27 55 10 24 92	28 04 67 53 44	95 23 00 84 47
93 05 31 03 07	34 18 04 52 35	74 13 39 35 22	68 95 23 92 35	36 63 70 35 33
21 89 11 47 99	11 20 99 45 18	76 51 94 84 86	13 79 93 37 55	98 16 04 41 67
95 18 94 06 97	27 37 83 28 71	79 57 95 13 91	09 61 87 25 21	56 20 11 32 44
97 08 31 55 73	10 65 81 92 59	77 31 61 95 46	20 44 90 32 64	26 99 76 75 63
69 26 86 86 13	59 71 74 17 32	48 38 75 93 29	73 37 32 04 05	60 82 29 20 25
41 47 10 25 03	87 63 93 95 17	81 83 83 04 49	77 45 85 50 51	79 88 01 97 30
91 94 14 63 62	08 61 74 51 69	92 79 43 89 79	29 18 94 51 23	14 85 11 47 23
80 06 54 18 47	08 52 85 08 40	48 40 35 94 22	72 65 71 08 86	50 03 42 99 36
67 72 77 63 99	89 85 84 46 06	64 71 06 21 66	89 37 20 70 01	61 65 70 22 12
59 40 24 13 75	42 29 72 23 19	06 94 76 10 08	81 30 15 39 14	81 83 17 16 33
63 62 06 34 41	79 53 36 02 95	94 61 09 43 62	20 21 14 68 86	94 95 48 46 45
78 47 23 53 90	79 93 96 38 63	34 85 52 05 09	85 43 01 72 73	14 93 87 81 40
87 68 62 15 43	97 48 72 66 48	53 16 71 13 81	59 97 50 99 52	24 62 20 42 31
47 60 92 10 77	26 97 05 73 51	88 46 38 03 58	72 68 49 29 31	75 70 16 08 24
36 88 87 59 41	06 87 37 78 48	65 88 69 58 39	88 02 84 27 83	85 81 56 39 38
22 17 68 65 84	87 02 22 57 51	68 69 80 95 44	11 29 01 95 80	49 34 35 86 47
19 36 27 59 46	39 77 32 77 09	79 57 92 36 59	89 74 39 82 15	08 58 94 34 74
16 77 23 02 77	28 06 24 25 93	22 45 44 84 11	87 80 61 65 31	09 71 91 74 25
78 43 76 71 61	97 67 63 99 61	80 45 67 93 82	59 73 19 85 23	53 33 65 97 21
03 28 28 26 08	69 30 16 09 05	53 58 47 70 93	66 56 45 65 79	45 56 20 19 47
04 31 17 21 56	33 73 99 19 87	28 72 39 27 67	53 77 57 68 93	60 61 97 22 61
61 06 98 03 91	87 14 77 43 96	43 00 65 98 50	45 60 33 01 07	98 99 46 50 47
23 68 35 26 00	99 53 93 61 28	52 70 05 48 34	56 65 05 61 88	90 92 10 70 80
15 39 25 70 99	93 86 52 77 85	15 33 59 05 28	22 87 26 07 47	86 96 98 29 06
58 71 96 30 24	18 46 23 34 27	85 13 99 24 44	49 18 09 79 49	74 16 32 23 02
93 22 53 64 39	07 10 63 76 35	87 03 04 79 88	08 13 13 85 51	55 34 57 72 69
78 76 58 54 74	92 38 70 96 92	52 06 79 79 45	82 63 18 27 44	69 66 92 19 09
61 81 31 96 82	00 57 25 60 59	46 72 60 18 77	55 66 12 62 11	08 99 55 64 57
42 88 07 10 05	24 98 65 63 21	47 21 61 88 32	27 80 30 21 60	10 92 35 36 12
77 94 30 05 39	28 10 99 00 27	12 73 73 99 12	49 99 57 94 82	96 88 57 17 91

II. PHYSICAL SAMPLING

The following items should be considered when you are ready to sample:

- Type of sample to be collected (*i.e.* grab vs. composite)
- Sampling equipment

A. TYPE OF SAMPLE

As noted in Table 2.4-1, N represents the number of discrete samples to be collected prior to compositing. Discrete, or grab, samples are defined as simple "dip and take" samples that can be collected with any of the sampling equipment listed in Table 2.4-3 Prior to collecting the samples, determine the total volume of biosolids needed for the required analyses. By doing so, you can better determine the amount needed from each discrete sample.

Table 2.4-1 lists the number of grab samples to be collected and also the number of composite samples required for analysis. Biosolids consistency will range from liquid (soupy), semiliquid (slurry), semisolid (muddy), to solid (dry); therefore, different methods of compositing apply. If the biosolids are in a liquid, semiliquid, or semisolid state, mix the individual grab samples in an appropriate container, and stir well, ensuring a complete mix. If the biosolids are in a solid state, combine all of your grab samples into one cone and then quarter the biosolids cone at least twice, to form a homogeneous composite sample.

To cone and quarter, place all samples into a ring (like a doughnut) on a smooth surface (*e.g.*, a smooth crack-free concrete surface or a large smooth synthetic material tarpaulin). Start at any point on the ring and move around the ring shoveling one scoop at a time to the center of the ring to form a pile. Each scoop should placed on top of the center of the pile so as to allow the biosolids to fall on all sides of the pile. After all the biosolids have been placed in the pile, flatten the pile so as to level out the pile into a large wafer. Divide the wafer into quarters and discard two opposite quarters and keep one quarter for analysis and the second for a replicate sample.

Please note that compositing of samples is not applicable to volatile organic sampling and analysis. Volatiles must be collected and analyzed as grab samples or may be composited in the lab prior to analysis.

B. SAMPLING EQUIPMENT

The types of sampling techniques and equipment needed will vary depending on the physical characteristics of the biosolids and the configuration of the biosolids body. The sampling plan should also include a list of the sampling devices or equipment, sample containers, and other miscellaneous materials that are essential during the actual field sampling. The following paragraphs provide information on the various types of sampling devices available.

A coliwasa sampling device can be used to collect a core sample of free-flowing liquid biosolids from biosolids lagoons, tanks, pits, and similar contaminants. The coliwasa consists of a metal, plastic, or glass tube with a stopper attached to the bottom that can be opened and closed while the tube is submerged in the liquid biosolids to be sampled. The coliwasa is lowered into the biosolids at a slow rate to allow the level of liquid inside and outside the sampler to stay the same. When the tip of the sampler contacts the bottom, the stopper is closed and the biosolids inside are trapped. This sample represents the entire depth of the biosolids. A typical coliwasa measures about 5 feet in length. Longer coliwasa of 10 to 15 feet in length are available commercially.

A thief sampler can be used to sample granulated or powdered biosolids. The thief is constructed of two slotted concentric stainless or brass tubes. The outer tube has a conical pointed tip which allows the sampler to penetrate the material being sampled. The sampler can be closed by rotating the inner tube. Thiefs of about 2 to 4 feet in length are available.

A trier sampler can be used to sample sticky (mud-like) biosolids. The trier consists of a stainless steel or brass tube that is cut in half lengthwise and one tip sharpened to allow proper penetration into muddy or loose solids, with particle diameters of less than one-half the tube diameter. Triers of up to 4 feet in length and 1 inch in diameter are generally available.

Augers, shovels, and scoops can be used to sample powdered, granulated, or hard packed solid biosolids. These items should be constructed preferably of stainless steel, but other materials may also be acceptable.

To avoid contamination (*e.g.*, zinc from galvanized equipment) care must be taken when choosing equipment. Glass and teflon would be ideal sampling equipment but stainless steel will work. Aluminum can be used. Plastics can be used but not for organics. Do not use material that will dissolve or be entrapped by the biosolids.

Table 2.4-4. Common Sampling Devices.

Sampling Device	Sample Size	Biosolids Make-up	Sampling Device Size
Composite liquid biosolids sampler (Coliwasa)	Cross section	Free-flowing liquid biosolids	Typically 5 feet in length (10 to 15 feet are available)
Thief sampler	Cross section	Granulated or powdered biosolids	2 to 4 feet in length
Trier sampler	Cross section	Sticky (mud-like) biosolids	Up to 4 feet long and 1 inch in diameter
Auger	Cross section and discrete samples	Hard packed biosolids	Variable
Shovel and Scoops	Discrete samples	Granulated, powdered, or loose biosolids	Variable

Additional Resources

Further guidance on taking soil samples can be found at the following Internet addresses:

BIOSOLIDS REFERENCE SHEET

1. *How to Get a Good Soil Sample* by Daryl D. Buchholz, Department of Agronomy, University of Missouri-Columbia: http://www.muextension.missouri.edu/xplor/agguides/soils/g09110.htm

2. *Soil Sampling* by J.R. Self and P.N. Soltanpour, Colorado State University: http://yuma.colostate.edu/Depts/CoopExt/PUBS/CROPS/00500.html

3. *How to Take a Soil Sample...and Why* by E. Hugh Gardner, revised by John Hart, Oregon State University Extension Service: Publication EC 0628; locate at http://eesc.orst.edu/agcomwebfile/edmat/

4. *›Tis the Season for Soil Sampling* by Manitoba Agriculture Department: http://www.gov.mb.ca/agriculture/news/topics/daa03d06.html

Guidance on interpreting analyses of soil samples can be found at the following addresses:

1. *Interpretation of Laboratory Analyses of Biosolids Samples* by James R. Brown and Dennis Sievers, University of Missouri-Columbia and Robert Magai, Missouri Department of Natural Resources: http://muextension.missouri.edu/xplor/waterq/wq0429.htm

2. Soil Test Interpretation Guide by E.S. Marx and John Hart, Oregon State University and Bob Stevens, Washington State University: Publication EC 1478; locate at http://eesc.orst.edu/agcomwebfile/edmat/

SECTION 2.5 C BIOSOLIDS MANAGEMENT PLAN

In accordance with the Clean Water Act of 1987, EPA must include biosolids requirements in permits to protect public health and the environment. To determine appropriate requirements for land application, EPA needs information on current biosolids handling and use practices, and a 5-year biosolids operating plan which describes a City's biosolids marketing area and planning procedures for new sites (Biosolids Management Plan). This information must be included with the completed permit application. In addition, the plan acts as a blueprint for planned biosolids activities; its development is required by Part 503.

After approval of the Biosolids Management Plan by EPA, the Plan becomes an enforceable part of the permit. An outline of the major plan elements follows.

BIOSOLIDS MANAGEMENT PLAN

As part of an NPDES permit application in Region 8, a Biosolids Management Plan (Plan) must be submitted to EPA. The Plan includes current biosolids practices and a 5-year biosolids operating plan which includes the following elements:

A. A description of the permittee's biosolids production and any current and known future land application sites.

B. A list of the counties (and states if applicable) where the permittee may want to market or distribute its biosolids over the life of the permit (5 years minimum). A copy of the plan must be submitted to the appropriate State Health Department, and should be submitted to the State Extension Service Office in the counties where biosolids may be marketed.

C. Site selection criteria to be used when identifying new land application sites.

D. Site management practices relating to, at a minimum: floodplain, slope, depth to ground water, weather conditions, soil conditions (compaction, permeability, saturated, frozen, snow-covered), site access, and protection of surface waters, wetlands, endangered species, and underground drinking water sources at current sites; and operating procedures (*e.g.*, qualified soils consultant, Soil Conservation Service, State Extension Service) for annual adjustments and for setting site management practices for future sites.

E. Buffer zones between biosolids application sites and: surface waters, drinking water wells, drainage ditches, property lines, residences, schools, playgrounds, airports, public roadways, and any necessary site-specific buffer zones for current sites; and operating procedures (*e.g.*, qualified soils consultant, Soil Conservation Service, State Extension Service) for making annual adjustments and for setting buffer zones for future sites.

F. Storage provision for biosolids during periods when biosolids cannot be land applied.

G. Either Alternative Pollutant Limits, or maximum acceptable annual and total cumulative application rates, expressed as kilograms per hectare (kg/ha), for (as a minimum) arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc; any other pollutants regulated by the Part 503 rules.

H. Maximum acceptable biosolids application rate to assure that the amount applied does not exceed the nutrient requirements of the particular crop grown on the application site (agronomic rates) for current year crops, and operating procedures (*e.g.*, qualified soils consultant, Soil Conservation Service, State Extension Service) for making annual agronomic rate adjustments and for setting agronomic rates for future sites.

I. A description of the pathogen treatment, vector attraction control, record keeping, monitoring, certifications, and notifications as required by the 40 CFR Part 503 regulations.

J. Reference to applicable regulations (40 CFR Part 503) and procedures the permittee intends to use to ensure that biosolids practices and limits outlined are followed.

K. Information described in 40 CFR 501.15(a)(2).

L. Public notice procedures and procedures for advance notice to EPA (at least 60 days) of proposed new land application sites.

M. Procedures, or copies of documents specifying procedures (*e.g.*, contracts) that will be used to ensure compliance with this permit and applicable regulations if the permittee contracts with others for assistance to select and/or manage the land application sites itself.

N. Contingency plans that describe disposal options for any biosolids which do not meet the requirements for land application or exceeds storage capacity.

O. A statement (*e.g.*, city ordinance) that the permittee will comply with the Biosolids Management Plan, as approved by EPA.

P. A statement that the Plan will be amended to reflect any applicable practices or limits EPA promulgates pursuant to Section 405 of the Act.

For further information, see EPA Office of Wastewater Management, **Environmental Management Systems: An Implementation Guide for Small and Medium-Sized Organizations**, available for download at http://www.epa.gov/owmitnet/wm046200.htm.

SECTION 2.6 C PUBLIC EDUCATION

A POTW that attempts to use biosolids in a beneficial manner may encounter public opposition. Public education and outreach activities can help to disseminate accurate information, which can go a long way toward community acceptance of biosolids recycling. Below are some resources that may prove helpful.

The Water Environment Federation (WEF) has a Biosolids Recycling Public Awareness Program (see http://www.wef.org/docs/publicout.html) which describes the importance of biosolids recycling and the advantages of beneficial use. WEF has developed video and information kits for use in local campaigns, aimed at community opinion leaders and the general public. Videos are approximately 12 minutes long and are individualized by region; the kits contain quotes from local spokespersons, fact sheets, and biosolids brochures.

WEF has other materials available (http://www.wef.org/biosolids.html), including:

- *Quotes From Experts* on the land application of biosolids
- *Biosolids Technical Bulletin*, a bi-monthly technical newsletter on every aspect of biosolids management
- A press release on residuals and biosolids management
- Correcting *The Case for Caution*; a point-by-point critique of the Cornell Waste Management Institute document
- WEF/EPA Biosolids Fact Sheet Project (see below)
- *Biosolids Recycling Facts*
- *Biosolids Recycling: An Environmentally Sound Way to Put a Valuable Resource to Work for All of Us*
- *Biosolids Recycling: Beneficial Technology for a Better Environment*
- *Biosolids Recycling Public Awareness Program* - Biosolids Information Kit

WEF and EPA have a joint Biosolids Fact Sheet Project, which is a compilation of information concerning biosolids applications or issues. The materials deal with a group of controversial incidents created when municipal treatment plant residues were used or considered for use as beneficial resources. The resultant public debate perhaps did not always serve the interests of accuracy. The fact sheets are as follows and can be downloaded at http://www.wef.org/docs/biofact:

- *Biosolids Recycling in West Texas*
- *Biosolids in Southern California*
- *Biosolids in Northern Washington State*
- *Biosolids and Miniature Horses in Oklahoma*
- *Can AIDS Be Transmitted by Biosolids?*
- *Biosolids and Bahamian Papaya Crops*
- *Biosolids Application to Forestland in the Pacific Northwest*
- *Biosolids and Lou Gehrig's Disease*
- *Biosolids Application to Federal Land*

In addition, information sheets are available, entitled *Biosolids Radionuclide Information Sheet* and *Dioxin Information Sheet.*

EPA=s Office of Wastewater Management (http://www.epa.gov/owmitnet/bio.htm) has a rejoinder to the 3-part series on biosolids aired on CNN in June 1997 entitled AHazardous Harvest@ which portrayed biosolids as a poison to food and animals.

A pamphlet entitled *Fertilizing with Biosolids* by Dan Sullivan of Oregon State University provides an excellent summary of the issues, including nutrient information, soil quality, questions and answers, etc. It can be found at http://wwwagcomm.ads.orst.edu/AgComWEBFile/EdMat/PNW508.pdf. It could be an appropriate handout at public meetings, open houses, etc.

LOCAL PROGRAMS

Many local agencies have public education programs and materials available. Some examples:

C Boulder, CO Dept. of Water Quality & Environmental Services publishes a *Waste Newsletter*; an issue concerned with biosolids can be downloaded at http://www.publicworks.ci.boulder.co.us/depts/utilities/water_quality/waste_news/waste_0698.htm

C Harford County, MD has downloadable materials on its biosolids recycling program, including Frequently Asked Questions and *Outstanding in Our Fields* at - http://www.co.ha.md.us/dpw/ws/biosolids.html.

C The University of California Sustainable Agriculture Research and Education Program (SAREP) has a description of its Information, Education and Outreach Program at - http://www.sarep.ucdavis.edu/Pubs/ProgressReport/95-97/information.htm.
Some of its activities include publications, a newsletter, workshops and conferences (including California Biosolids Conference in 1997), school gardening programs, and outreach directed to farmers and ranchers.

C King County, Washington Department of Natural Resources has participated in King County=s Partners in Public Education (PIPE) program: grants from the Water Pollution Control Division provided the impetus for urban horticultural gardens and tree plantings at area middle schools as well as other projects, described at http://waterquality.metrokc.gov/pipe1/pipe.htm.

C Hampton Roads (VA) Sanitation District has a description of its compost, land application, incinerator ash recycling, and research and demonstration programs at http:www.hrsd.state.va.us/biosolids.htm. The District Public Information and Education staff has materials for schools and interested community members, including video tapes designed for children. Staff scientists, water quality and water treatment professionals, laboratory staff and others are available to talk with community and school groups. The Public Information office can be reached at (757) 460-7049; see http://www.hrsd.state.va.us/edu.htm.

BIOSOLIDS Q & A, which follows, is a compilation of commonly asked questions and answers regarding biosolids and land application, as well as additional sources for information. Especially helpful in this compilation were biosolids fact sheets from the Sacramento Regional County Sanitation District and the Rocky Mountain Water Environment Association.

General Biosolids Questions

What are biosolids?
Biosolids are the nutrient-rich organic byproducts of wastewater treatment. Biosolids consist of treated solid, semi-solid, or liquid residues removed from wastewater during the cleaning process. When solids are initially separated from wastewater they are about 99 percent water. Biosolids are produced in several forms including a liquid, a rich hydrous soil, a dried pellet or a compost material.

Biosolids are not raw human waste and do not include animal manure, untreated septage, municipal solid waste, hazardous waste, industrial sludges such as those generated from oil and gas refineries, or grit and screenings collected during preliminary wastewater treatment.

What is the difference between Abiosolids@ and Asewage sludge@?
Although often equally interchanged in discussion about wastewater treatment residue, there is a technical difference between the terms Asewage sludge@ and Abiosolids@. As wastewater is physically and biologically treated, organic and inorganic compounds are removed. The byproduct formed through this process is called sewage sludge, and can consist of organic matter, nutrients, dissolved minerals, pathogens and toxic contaminants. From this point, the sludge is further treated, as required by both Federal and State regulations. This treatment is necessary to remove pathogenic microorganisms and other harmful and excessive constituents from the sludge. The result of this additional treatment is a nutrient-rich organic material called Abiosolids.@

Where do biosolids come from?
Households generate wastewater. When showers are taken, laundry is washed and toilets are flushed, clean water is converted into wastewater. Businesses and industries also generate wastewater. Most wastewater, a combination of soap suds, toilet paper, and organic matter, travels through an extensive plumbing and sewer system until it reaches the domestic wastewater treatment plant. At the local wastewater treatment plant, the wastewater is cleaned prior to discharge into a river, lake or stream.

The by-product of the wastewater treatment process is a natural organic material called sewage sludge. The sewage sludge is further treated to produce a nutrient-rich organic material called biosolids, suitable for use as a natural fertilizer and soil conditioner. Biosolids have long been beneficially used by farmers, horticulturists, land use specialists, and the public throughout the United States and the world. The U.S. Environmental Protection Agency regulates and encourages the recycling of biosolids through land application.

What are the most common biosolids use and disposal methods?
In the past, the United States primarily disposed of their sewage sludge in landfills, in storage lagoons, dumped the sludge in the ocean, or had it incinerated. For a variety of reasons, these disposal methods have become less favorable and the land application of biosolids is being encouraged. Although most of the past disposal methods are still used, land application of biosolids is considered a more desirable option because it returns useful resources to the land, replenishing the soil with nutrients and organic matter.

Throughout the past 25 years, land application of biosolids has substantially increased, the percentage more than doubling since 1976. In 1995, 54 percent of all biosolids produced in the United States were beneficially used for land application. Table 1 below displays the progression of land application of biosolids from 1976 to 1995.

Table 2.6-1. Biosolids Disposal Trends (1)

Management Method	1976[1]	1978[2]	1981[3]	1988[4]	1995[5]
Land Application, composting, heat drying, alkaline stabilization, etc.	25%	31%	42%	48%	54%
Landfill, Surface Disposal in Lagoons	25%	29%	15%	31%	18%
Incineration	35%	22%	27%	14%	19%
Ocean Disposal	15%	12%	4%	5%	0%
Other (Lagoons, etc)		6%	12%	2%	9%

Sources:

[1] USEPA 1976. Municipal sludge management: EPA construction grants program, an overview of the sludge management situation EPA 430/9-76-009, MCD-30

[2] USEPA 1976. Comprehensive sludge study relevant to Section 8002(g) of the RCRA of 1979. SW-802

[3] Prepared for USEPA by Booze-Allen and Hamilton, Inc. Bethesda, MD

[4] National Sewage Sludge Survey; Availability of Information and Data, and Anticipated Impacts on Proposed Regulations; Proposed Part 503 Rule. FR55 No. 218, November 9, 1990.

[5] Bastian, R.K., 1997. The Biosolids (Sludge) Treatment, Beneficial Use, and Disposal Situation in the USA. European Water Pollution Control 7#2:60-79.

Why not incineration?
Incineration is very expensive and is often not a viable option because of existing air quality.

Why not landfill disposal?
Disposing of biosolids in landfills is a safe and viable option, but often not a preferred option. Studies have shown that the addition of biosolids can benefit the operation of a landfill by increasing the rate of organic matter decomposition, resulting in more efficient methane gas recovery and improving the quality of leachate collected from the landfill. However, because landfill space is often quite limited, competition with municipal or industrial solid waste contributors causes landfill disposal to be an expensive option.

Why not ocean disposal?
In 1989, Congress banned the act of ocean disposal of biosolids. Ocean dumping of biosolids was not banned due to any observed toxic effects of biosolids to marine life, but because it is more logical and beneficial to promote land application of biosolids. The same nutrients in biosolids that are beneficial on land are considered pollutants in water. Land application provides a method for positively utilizing the nutrients present in biosolids, enhancing and replenishing the soil. However, when the same nutrients are deposited into the ocean, the health of the marine environment is put at risk. Excess nutrients and organic matter in a waterbody can result in algal blooms. The increased presence of algae can deplete the water of the oxygen necessary to support other aquatic life. This process is called eutrophication. Congress properly decided is was more sensible to halt the dumping of biosolids into the ocean and use the nutrient-rich substance safely and productively to provide crop nutrients and improve soil quality through land application.

Where are biosolids land applied?

In the United States, biosolids have been beneficially used in a number of ways. Biosolids are land applied to agricultural cropland to enrich the soil with essential nutrients and organic matter for growing crops such as corn, soybeans, grains, hay, and pasture and are applied to rangeland. Biosolids are also land applied to non-agricultural land areas such as forests, parks, cemeteries, golf courses, and land-reclamation sites. Biosolids can even be applied to individual lawns and gardens.

Land Application to Agricultural Land

Biosolids are land applied to agricultural cropland and rangeland to enrich the soil with nutrients and organic material. The biosolids act as a natural fertilizer, providing essential nutrients such as nitrogen and phosphorus. Biosolids are also a valuable soil conditioner, supplying organic matter that improves the soil water retention among other beneficial effects. To ensure safe levels of nutrient application, biosolids must be applied at a rate that is equal or less than the agronomic rate. Agricultural land application is practiced in nearly every state. Agricultural land application is a positive and encouraged program because it benefits both the treatment facility, by providing an environmentally acceptable and cost effective means of solids disposal, and the participating farmer, who benefits from the improved soil conditions.

Land Application in Forests

Biosolids are land applied in forests to promote timber growth. The application of biosolids has been found to increase timber growth, allowing for faster and more efficient harvesting and replenishment of an important renewable resource. Studies at the University of Washington on the use of biosolids as a fertilizer in silviculture showed height increases of up to 1,190 percent and diameter increases of up to 1,250 percent compared to controls in certain tree species (11-Environmental Regulations and Technology, AUse and Disposal of Municipal Wastewater Sludge@, September 1984). Unfortunately, the rough topography of forest land often requires special application vehicles for land application, unless the land contains adequate road systems.

Land Application in Parks

Commercial biosolids products are safe and effective for use as fertilizers and soil amendments in lawn and garden applications. Biosolids compost has been applied on many public parks and athletic fields, including the athletic fields of the Los Angeles Dodgers, the California Angels and at the Rose Bowl. Biosolids compost has also been applied on the White House lawn, lawns at Mount Vernon, the Washington Monument, the Constitution Gardens on the Washington D.C. Mall and the Governor=s Mansions in Maryland and New Mexico.

Land Application to Reclamation Sites

Biosolids are rich in nutrients such as nitrogen and phosphorus, along with other supplementary nutrients in smaller doses, such as potassium, sulfur, magnesium, calcium, copper, and zinc. The nutrient-rich composition of biosolids creates an excellent soil amendment for soils that lack in these substances. Through the land application of biosolids, damaged land can be reclaimed. This practice has been applied to strip-mined land across North America and the world, nourishing and restoring the top soil, enabling vegetation to grow and flourish once again. Biosolids have also been applied at U.S. Superfund locations nationwide to replenish the cleanup sites.

Land Application to Home Lawns and Gardens

Biosolids in the form of compost can be applied on individual home lawns and gardens. The compost product, labeled as Class A biosolids, is required to undergo rigorous pathogen destruction treatment to ensure safety for home use, where direct contact is more likely. The biosolids compost product is often available at participating local wastewater treatment plants, or at local nurseries and gardening supply stores.

One of the best known biosolids compost products on the market is Milorganite. In 1926, the city of Milwaukee, Wisconsin created a compost product from its heat-dried biosolids and has marketed the product, Milorganite, to the public ever since. Other such products for sale are Houactinite from Houston, Nitrohumus from Los Angeles, ComPRO from the Washington, D. C. Suburban Sanitary Commission and MetroGro from Denver.

How does the land application of biosolids affect groundwater pollution?

Cropland application:
The greatest challenge in using biosolids for beneficial reuse on crop- and rangeland is to prevent N03- 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 N03- should not occur. Annual monitoring of residual soil N03- N levels will help guard against groundwater pollution.

Can biosolids applied to land contaminate groundwater? Biosolids present no greater threat to groundwater than animal manures or commercial fertilizers, because biosolids are applied to land at rates that meet the fertilizer requirements of the crops to be grown. Over many decades, thousands of acres of crop land have successfully received biosolids applications. In states where water quality monitoring wells are required, the water quality from these wells has always shown that when biosolids are used at agronomic rates following good agricultural practices, there is no degradation of groundwater quality attributable to biosolids. Studies show that when biosolids or fertilizers are properly applied and crops are harvested from the site, there is no increase in nitrate concentrations in the groundwater.

As with any incorrectly applied agricultural product, the soluble constituents of biosolids have the potential to impact groundwater. The primary concern for groundwater quality associated with biosolids land application is with nitrate levels. Biosolids are normally applied at an agronomic rate, which means that the crop receives only the amount of nitrogen it can absorb. During the growing process, the crop takes up the nitrogen, thus removing the nitrogen from the site when the crop is harvested. Only when more than the agronomic amount of biosolids is applied can there be excess nitrogen that eventually will be converted to nitrates, which could migrate to the groundwater.

Will the metals in biosolids pollute the groundwater?
No. Extensive research over many years has found that trace metals are strongly adsorbed or held to the soil and organic matter added with biosolids and native to the soil. Except under very acidic conditions (pH <5.5) metals are tightly bound and are neither mobile for leaching to groundwater or soluble for uptake into plants.

Will pathogens end up in our groundwater?
No. Pathogens in biosolids are extremely unlikely to find their way into groundwater. During biosolids treatment, the concentration of pathogens is significantly reduced and bacterial levels are usually found to be less than those in manure. Researchers have found that the smallest pathogen, viruses, are very strongly bound to biosolids and are not easily released even after
rainfall or irrigation.

Will biosolids pollute the groundwater with trace organic compounds and pesticides?
No. Trace organic compounds are rarely found in biosolids prior to land application. Recent studies show that these organic compounds are highly volatile and are not present in biosolids or the soil long enough to be of concern for groundwater quality.

Are monitoring wells needed at application sites?
No. Research over the past 30 years, including the use of lysimeters, shallow wells, and deep wells, have found that biosolids pose little risk to groundwater quality. It is not necessary to install wells as long as biosolids are applied at agronomic rates and the site is farmed following normal best management practices.

How is groundwater quality protected from biosolids?
Groundwater buffers of at least 20 feet deep protect groundwater from direct contamination by biosolids. By applying at agronomic application rates and using biosolids with acceptable quality, the groundwater under the application site is protected from becoming contaminated by nitrates, pathogens, and trace metals. All wells provide a potential direct path to groundwater, and have similar buffer requirements regardless of how they are used (e.g., for irrigation or domestic water supply). A well that has been abandoned may provide a direct path to groundwater if it has a cracked or nonexistent well casing.

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Biosolids Regulations

How are biosolids regulated?

Regulations governing the beneficial use of biosolids were developed under the authority of the federal Clean Water Act. The federal Part 503 regulation (40 CFR 503), in conjunction with state regulations, ensure that the production and use of biosolids is a safe and integral part of this country=s water quality and waste management programs. The Part 503 sludge regulations detail the comprehensive requirements for the management of all biosolids generated from the wastewater treatment process. The Part 503 regulation is a comprehensive, risk-based regulation that protects human health, conservatively based on the Ahighly exposed individual@, and the environment, including the impact of biosolids on groundwater, air and soil quality and surface runoff. This regulation was subjected to extensive scientific peer review, public notification, and public hearings across the nation prior to adoption.

What are the requirements of the Part 503 sludge regulations?

The U.S. Environmental Protection Agency promulgated a regulation at 40 Code of Federal Regulations (CFR) Part 503 to ensure that biosolids are used or disposed of in a way that protects human health and the environment. Part 503 imposes requirements for a variety of biosolids use or disposal methods, including surface disposal, and incineration and land application.

The EPA=s Part 503 rule encourages the beneficial reuse of biosolids through land application, and it establishes strict standards under which wastewater residuals can and cannot be beneficially recycled as soil amendments. The EPA believes that biosolids are an important resource that can and should be safely recycled. The 503 rule contains seven basic types of requirements for the land application of biosolids. The seven restriction categories are general requirements, pollutant limits (metals), operational standards for pathogen and vector attraction reduction, management practices, frequency of monitoring, record keeping, and reporting. The number of applicable requirements for land application under Part 503 will depend upon the quality of biosolids being applied, as well as whether the biosolids will be applied in bulk form or sold or given away in a bag or other container for application to the land. For more information on the Part 503 regulations for land application of biosolids refer to 40 CFR 503, available at a local library, or available on the internet at http://www.biosolidsinfo.com.

What are the obligations of those involved in land application of biosolids?

The responsibilities of the **biosolids producer** are to:

T Create biosolids suitable in quality for the intended use.

T Document and certify the quality of the biosolids.

T Maintain records, prepare annual reports, and deliver information as required.

T Ensure that all-applicable Federal, state, and local requirements are met when biosolids are applied to land, even if other parties are contracted to supply any or all of these services.

The responsibilities of the **biosolids transporter** are to:

- Maintain a fleet of licensed, clean vehicles suitable to the performance needs of the transportation task.
- Select and train qualified, licensed drivers.
- Load, deliver, and unload biosolids without creating a nuisance.
- Maintain records and deliver information as required.

The responsibilities of **biosolids applier** are to:

- Know the quality of biosolids provided by the Generator and be certain that it is suitable for agricultural land application. This encompasses biosolids quality for trace metals, toxins, pathogens, vector attraction, and nutrients.
- Obtain appropriate permits for sites of the biosolids application. Maintain these permits over the operating life of the site.
- Perform appropriate management practices including buffers from neighbors, buffers from site features such as waterways, control access to the site, and integrate the biosolids application with the farm operations.
- Meet operational standards for pathogen and vector attraction reduction in certain circumstances.
- Apply biosolids to the site in a safe and expeditious manner that benefits the growing process while not in conflict with weather conditions or potentially threatened or endangered species.
- Monitor the biosolids and the site.
- Ensure, document, and certify that the applied biosolids meets all regulatory requirements.
- Supply to the land owner and/or lease holder of the site, information needed for that party to comply with Federal, State and/or Local permits.
- Maintain records, prepare annual reports, and deliver information as required.

The responsibilities of the **grower** are to:

- Know the quality of biosolids provided by the Generator and/or Applier and be certain that it is suitable for use on the Grower's farm land. This encompasses biosolids quality for trace metals, toxins, pathogens, vector attraction, and nutrients.
- Perform appropriate management practices including buffers from neighbors, buffers from site features such as waterways, control access to the site, and integrate the biosolids application with the farm operations.

- T Harvest crops consistent with the requirements established in Part 503 regulations.
- T Maintain records, prepare annual reports, and deliver information as required.

What are the penalties for not complying with the biosolids regulations?
Enforcement and penalties for not complying with the biosolids laws and regulations are potentially severe and may be either civil or criminal. The worst case criminal circumstance for violation of the Clean Water Act occurs if a person knowingly violates the law and knows that he thereby places another person in imminent danger of death or serious bodily injury. Upon conviction of such a charge, the violator can be subject to a fine of not more than $250,000 or imprisonment of not more than 15-years, or both. If the violator is a company or municipality the fine may rise to $1,000,000. If a person is a repeat offender of these provisions, the maximum punishment shall be doubled. At this time, there have been no known severe criminal offenses for biosolids mismanagement.

How do the biosolids regulations in the United States compare to European standards? Why do they differ?
Some European biosolids management standards are somewhat different and more restrictive than United States standards, especially relating to trace metal concentrations. These differences arise from fundamentally different approaches to regulating the addition of trace metals to agricultural soils. Several European nations have formulated their regulations on the basis of preventing trace metals from accumulating above natural background levels (or current levels) in soils. The United States Part 503 Regulation uses the approach of allowing application of trace metals so long as the soil capacity for assimilating, attenuating, and detoxifying is adequate to minimize the risk to humans, crops, and the environment. The U.S. EPA found this approach to adequately protect public health and the environment while allowing the beneficial reuse of biosolids for its nutrients, trace elements, and organic matter.

Are the metals not currently covered by EPA=s Part 503 regulation a concern?
No. Extensive research on the quality of biosolids and its interaction with soils and crops shows that the other 58 trace metals are either innocuous, are an essential element, or are not present at concentrations to be of concern.

Why are the 503 standards changing after they were implemented?
The U.S. EPA is required by law to maintain an ongoing program to evaluate the effects of pollutants and the latest research results to determine if any changes in regulations are warranted. Also, from time to time, organizations sue EPA when they believe EPA=s facts or science are incorrect. These activities result in occasional changes such as the recent deletion of selenium and molybdenum from certain regulatory tables.

Why does EPA regulate carcinogenic chemicals in biosolids at a risk level of 1 in 10,000 and pesticides at 1 in 1 million?
U.S. EPA chose a risk level standard of 1 in 10,000 for two primary reasons. First, EPA has some latitude in choosing risk levels within a range of 1 in 10,000,000 to 1 in 10,000. Choices within this range are a function of the underlying science, uncertainties, and information bases. EPA chose the lower risk level because the use of biosolids on farm crops did not show a significant overall risk from its use. Also, when EPA chose to use the Ahighly exposed individual@ (HEI) as the target for risk assessment, a number of very conservative assumptions were incorporated into the analysis. For example, in adult cases the individual is expected to use the same garden or water well for 40% of their food for 70 years continuously, 365 days per year. Because of the conservative assumptions and the HEI, the effective risk to the general population is 1 in 10,000,000.

Biosolids Management

What are the different forms of biosolids?

Biosolids are produced in several forms, depending upon the percent of total solids. Use of the different biosolids products will determine the method and timing of land application.

Liquid

Liquid biosolids are a readily flowing product consisting of both solids and water. The percentage of solids is usually between 2-5%, but can be as high as 10% or as low as 0.5%.

Dewatered

Dewatered biosolids are more concentrated than the liquid form. This product is produced by mechanically removing liquid from the biosolids. The byproduct, dewatered Acake@, usually contains between 16-22% solids, but can be composed of as high as 40% solids. The use of dewatered biosolids is advantageous because of reduced hauling and storage costs, and the ability to apply the biosolids at higher application rates with a single pass of the equipment.

Air- or Heat-Dried

Dried biosolids are a more concentrated product, the result of air drying or heat drying treatment. The solids content of this product is typically around 50%.

Compost

Composted biosolids are produced when biosolids are mixed together with a bulking agent such as sawdust or recycled compost. The mixture is aerated under controlled temperatures in accordance with Part 503 regulations. The solids content of the composted product is usually about 40%.

What are the major methods of applying biosolids?

The method of land application of biosolids will vary, depending upon the form of biosolids used. The land application method options are discussed below.

Liquid Biosolids

Application of biosolids in a liquid form is relatively simple. Dewatering processes are not required, and the liquid biosolids can be readily pumped. Application systems used with liquid biosolids include vehicular surface application by tank truck or tank wagon spreading, subsurface application by subsurface injection or disking methods, and irrigation application by spray irrigation or flood irrigation (gravity flooding). Liquid biosolids are often injected under surface soil layer to minimize odors.

Dewatered (Cake, Dried, and Composted)

Dewatered forms of biosolids are applied to land by surface application techniques. One method for surface application is spreading the dewatered biosolids with a truck-mounted or tractor-powered box spreader. This method spreads the biosolids evenly on the land. Another method for surface application of dewatered biosolids is to create large biosolids piles hauled by a dump truck. The spreading and leveling of biosolids must then be done by a bulldozer or grader. Upon spreading, the biosolids can then be incorporated by disking or plowing if desired.

When should biosolids be incorporated into the soil?
The need to incorporate biosolids into the soil depends on several factors. These factors include the potential odor of the biosolids, potential vector problems, the site location and the surface water runoff potential of the land application site. Incorporation is usually accomplished by discing the material into the top few inches (using standard agricultural equipment).

Can biosolids be applied to flooded, frozen, or snow-covered land?
The Part 503 regulation (40 CFR 503) does not prohibit the application of bulk non-EQ biosolids to flooded, frozen or snow-covered lands. In the effort to protect surface water from contamination during periods of cold and frozen conditions, the Part 503 regulation states that bulk sewage sludge (biosolids) applied to these lands may not enter wetlands or other waters of the United States, unless specifically authorized by a permit issued under Sections 402 or 404 of the Clean Water Act.

To prevent biosolids from entering wetlands or waters of the United States, land appliers must ensure proper runoff control measures are in place. These protective measures include actions such as slope restrictions, buffer zones, tillage, dikes, and diversions.

Are biosolids application rates regulated?
To avoid overloading the soil with nutrients from biosolids, Part 503 requires that bulk non-EQ biosolids be applied at a rate that is equal to or less than the site-specific agronomic rate. The agronomic rate is an application rate designed to provide the appropriate amount of nitrogen needed by the vegetation and yet minimize the amount of nitrogen that passes below the root zone. Excess nitrogen passing below the root zone could result in nitrate contamination of the groundwater. The biosolids applier is responsible for ensuring the biosolids are applied at an appropriate rate.

Biosolids Quality Control

Are biosolids classified according to quality?
The Part 503 regulation (40 CFR 503) focuses on three parameters as a basis for determining biosolids quality:

$ The presence of **pollutants** (arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc)

$ The presence of **pathogens** (e.g., bacteria, viruses, parasites)

$ The biosolids= **attractiveness to vectors** (e.g., rodents, flies, mosquitos)

Biosolids that meet the most stringent Part 503 limits for all three above biosolids quality parameters are referred to as Exceptional Quality (EQ) biosolids. EQ biosolids are considered to be comparable to other common fertilizer products. EQ biosolids can be distributed and applied in bulk or sold or given away in a bag or other container for application to agricultural land, forest, public contact sites, reclamation sites, lawns, and home gardens. EQ biosolids can be applied to sites where the potential for contact with the public is high, such as on urban parkland or golf courses, without any restrictions.

Biosolids that are classified as EQ meet the following quality criteria:

$ Pollutants- Both ceiling concentration limits and pollutant concentration limits (Table 1 and Table 3, 40 CFR 503.13)

$ Pathogens- One of the Class A pathogen reduction alternatives (performed by preparer)

$ Vector Attraction- One of the sewage sludge vector attraction reduction options 1 through 8 (performed by the preparer)

Biosolids that do not meet the most stringent limits for any or all three of the sludge quality parameters (listed above) are referred to as non-EQ biosolids. For land application of non-EQ biosolids, Part 503 imposes a larger number and variety of requirements depending upon the degree to which the biosolids quality diverges from EQ. These requirements apply to both the biosolids and the land application site to ensure the same level of protection for human health and the environment as provided by the EQ biosolids.

Another way of categorizing biosolids is by class. The two biosolids classes, Class A and Class B, indicate the level of pathogen reduction measures taken. Class A biosolids undergo more extensive pathogen destruction treatment so they can be used in home gardens, on lawns, in parks, on golf courses and in other places where the public could come in direct contact. Class B biosolids undergo less rigorous pathogen destruction that allows for safe application to agricultural fields where routine public contact does not occur.

How variable is the quality of biosolids?
Biosolids and sewage maintain a steady quality level. The quality of biosolids is slow to change because there is not much day to day variation in the characteristics of sewage entering the treatment plant. Also, residual solids remain in the treatment plant for processing for a minimum of 17 days, which tends to dilute any unusual characteristics.

Do pollutants from industrial discharges contaminate biosolids?
Controlling pollutants from industrial discharges before entrance into the sewer systems and wastewater treatment facilities assures that the biosolids generated are acceptable for recycling as a fertilizer or soil conditioner. The Industrial Pretreatment Program controls potentially harmful industrial discharges by restricting the discharge of major pollutants into the wastewater collection system, requiring pollutants to be treated or removed at the industrial plant from which they originate. Effective pretreatment programs have greatly reduced the level of contaminants in biosolids over the past two decades.

Are biosolids sampled frequently enough to ensure quality and safety?
Sewage, biosolids, and biosolids land application are frequently monitored to assure compliance with federal, state, and local requirements. Before the biosolids leave the treatment facility, the facility must certify to the U.S. EPA that the biosolids meet all the applicable regulatory standards. At the land application site, the biosolids applier must certify that the application meets all regulatory standards, as well. The certifications are backed by the power of the Federal Clean Water Act, which grants civil and criminal enforcement capabilities in situations where the standards are not being met.

Benefits of Land Application of Biosolids

How does the application of biosolids benefit the soil?

Biosolids enrich the soil with essential nutrients and organic matter. Biosolids contain many beneficial chemical constituents, often in both mineral and organic forms. The principal components, nitrogen, phosphorus and organic matter are significant in promoting plant growth and healthy soil conditions.

Nutrient Enhancement

Biosolids are a valuable source of nutrients for plant growth. Although the amount of nutrients in biosolids, predominantly nitrogen, phosphorus and potassium, are not as balanced as in commercial fertilizers, the essential plant nutrients provide beneficial impacts. Biosolids contain nitrogen in both organic and inorganic forms. Inorganic forms of nitrogen dissolved in biosolids are readily available for plant uptake. In this capacity, biosolids can serve as a quick-release fertilizer. Organic nitrogen in biosolids is gradually released through the process of mineralization and nitrification. This gradual release corresponds with the nitrogen needs of the growing crops, serving as a long-term, slow-release fertilizer. The slow nitrogen release properties of biosolids prevent excess available nitrogen from seeping into groundwater, a problem that occurs with the overuse of commercial fertilizers made with inorganic nutrient sources.

Organic Enrichment

Biosolids also add organic matter to the soil. Organic matter induces many beneficial physical, chemical and biological processes in the soil. The organic matter in biosolids causes soil particles to form clusters and tiny air pockets. The air pockets within the soil allow the soil to breathe as well as enable the soil to hold more water. The increased moisture retention results in decreased soil erosion, decreased surface water runoff and increased water conservation.

A study performed at Colorado State University concluded that the concentration of soil organic matter increased from 1.3% prior to biosolids application to 1.9% following application when biosolids were applied for four growing cycles (totaling 12 dry tons of biosolids applied per acre). This represents an overall organic matter increase of 46% (or approximately 10% per application).

How does a farmer benefit from land applying biosolids?

Farmers benefit from land applying biosolids in a number of ways. Not only are monetary gains realized, but also environmental benefits. These benefits of land application of biosolids to farmers are discussed below.

Increased Profits

Biosolids are typically applied and incorporated to suitable fields by the biosolids producer at little or no cost. As a result, an immediate and direct cost savings is realized. The land application of biosolids creates an opportunity for increased profitability through greater crop yields, better crop quality, reduced farm chemical use, lower tilling costs and increased water retention.

An 11-year study of biosolids application to dryland wheat by the Colorado State University Department of Soil and Crop Sciences showed an average biosolids generated profit of $18 per acre greater than that of anhydrous-applied areas (based on 50 to 60 bl. N./ac. Applied and an average 40 bu./ac. yield). Although much of this profit was due to the free cost of biosolids fertilizer, a smaller portion was due to the protein premium paid for a higher grain protein content.

Another dryland wheat study conducted in eastern Colorado by the Colorado Department of Public Health and Environment and the Environmental Protection Agency had resulted in an average farmer profit of $16 per acre greater than anhydrous-applied fields at a 38 bu./ac. yield. These profit gains may be used as a guide to estimate biosolids-generated profits for differing wheat yields or for other crop and farming applications. Generally, the greater the crop fertilizer requirement, the greater the direct profit potential from biosolids use. In addition to fertilizer savings, tillage cost savings of $5 per acre or more, depending on the type of tillage, may also be realized by the farmer if biosolids are incorporated at the time of application.

In 1993, a study was conducted by the Water Environment Research Foundation, studying crop yields on biosolids-applied land in Yuma, Arizona. Crop yields were found to be 10 to 85 percent higher than crop yields on soils receiving commercial fertilizers

Decreased Erosion and Surface Water Runoff

The land application of biosolids improves erosion control and surface water runoff. The organic matter in biosolids increases the moisture retention of the soil, improving soil tilth, root penetration and soil strength. When lacking in organic matter, soil becomes compact and water easily runs off, causing both erosion and insufficient moisture for plant growth. Adding biosolids, which are high in organic content causes soil particles to form clusters and tiny air pockets. The air pockets within the soil allow the soil to breathe as well as enable the soil to hold more water.

Decreased Ground Water Seepage

Biosolids contain organic nitrogen that is gradually released with the nitrogen needs of the growing crops, serving as a long-term, slow-release fertilizer. The slow nitrogen release properties of biosolids prevent excess available nitrogen from seeping into groundwater, a problem that occurs with the overuse of commercial fertilizers, made with inorganic nutrient sources.

Improved Crop Quality

It has been found that crops enhanced with biosolids return comparable dryland wheat yields to those of anhydrous ammonia, but consistently produce a higher grain protein content. An 11-year Colorado State University study has shown that biosolids-applied plots produced an average 15% greater grain protein than that of anhydrous ammonia-applied plots. The higher grain protein may be attributed to the slow release of organic nitrogen throughout the grain formation stage of the plant.

Biosolids vs. Other Soil Amendments

How do biosolids compare to manure?

In the United States the production of manure far exceeds the quantity of biosolids produced. According to the USDA, the estimated current annual production of manure by confined animals only, primarily cattle, sheep, pigs, and poultry exceed 61 million dry tons. By comparison, the total annual production of biosolids in the United States is about 7.7 million dry tons.

Recent data shows that about 50% of all biosolids are applied to land for beneficial purposes including agriculture, turfgrass production, mine reclamation, silviculture, and horticulture. Therefore, the amount of biosolids recycled annually is comparable to about 3 of the manure produced. A difference between animal manure use and biosolids recycling is animal manures use is generally unregulated. Application of animal manures is currently unregulated and can be applied to crop land without treatment to reduce pathogens. Biosolids applications, in contrast, are carefully regulated and are subject to loading rate restrictions, minimum treatment standards, and other requirements to ensure protection of human health and the environment.

The table below compares animal manure quality to biosolids quality and shows that they are roughly comparable. High quality biosolids can have heavy metal concentrations that are comparable to animal manures.

TABLE COMPARING COMPOSITION OF ANIMAL MANURES & BIOSOLIDS

Constituent (Unit)	Animal Manures Range	Biosolids Range	Typical Biosolids Value
Nitrogen (% dry weight)	1.7-7.8	<0.1-17.6	3.0
Total Phosphorus (% dry weight)	0.3-2.3	<0.1-14.3	1.5
Total Sulfur (% dry weight)	0.26-1.4	0.6-1.5	1.0
Calcium (% dry weight)	0.3-8.1	0.1-25	4.0
Magnesium (% dry weight)	0.29-1.0	0.03-2.0	0.4
Potassium (% dry weight)	0.8-4.8	0.02-2.6	0.3
Sodium (% dry weight)	0.07-1.0	0.01-3.1	N. A.
Aluminum (% dry weight)	0.03-0.2	0.1-13.5	0.5
Iron (% dry weight)	0.02-0.19	<0.1-15.3	1.7
Zinc (mg/kg dry weight)	56-566	101-27,800	1,200
Copper (mg/kg dry weight)	16-810	6.8-3,120	750
Manganese (mg/kg dry weight)	23-333	18-7,100	250
Boron (mg/kg dry weight)	20-143	4-757	25
Molybdenum (mg/kg dry weight)	2-14	2-976	10
Cobalt (mg/kg dry weight)	1	1-18	10
Arsenic (mg/kg dry weight)	12-31	0.3-316	10
Barium (mg/kg dry weight)	26	21-8,980	N. A.
Cadmium (mg/kg dry weight)	<0.1-1.6	<1-8,220	20
Lead (mg/kg dry weight)	<1-5.4	0.7-1,670	60
Mercury (mg/kg dry weight)	<0.1	0.2-47	1
Nickel (mg/kg dry weight)	5-7	2-976	10
Selenium (mg/kg dry weight)	<1	0.5-70	6

How do biosolids compare to commercial fertilizer?
Biosolids, as well as commercial fertilizer, contain significant amounts of nitrogen (N), phosphorus (P), and potassium (K). However, the nature of nutrients in biosolids is different than those found in commercial fertilizers. The nitrogen within commercial fertilizers is in an inorganic form, thus immediately available for plant uptake and mobility through leaching. Stabilization of biosolids during waste treatment produces nitrogen in organic forms that are not available to plants until they are decomposed by soil microorganisms. When biosolids are applied, microorganisms break down the nutrients and release 10 percent to 50 percent of the organic nitrogen as a plant-available nitrogen 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 nitrogen fertilizers that contain low concentrations of plant nutrients.

Often times, the physical soil changes resulting from biosolids application are more significant than the plant nutrients supplied. 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.

Biosolids Safety Concerns

Is the land application of biosolids safe?

Yes! When consistent with state and federal regulations, the transformation process of wastewater into biosolids ensures a product that is safe and suitable for land application. Industrial pretreatment controls ensure the concentrations of pollutants, such as metals and organic chemicals, are limited to very low levels. Treatment processes at the wastewater treatment plant are effective in destroying potentially harmful pathogens. Long-term scientific studies over decades have shown that biosolids recycling is both safe and beneficial.

Questions about the safety of land applying biosolids are common, not only among the general public but also by government policymakers and the scientific community. In response to the variety of concerns, no other agricultural practice or product has been subjected to such rigorous scientific assessment and risk evaluation as biosolids recycling. Scientific opinion about biosolids has evolved over the past four decades as increasing data has become available from long-term studies. Everything learned to date reinforces the safety and efficacy of biosolids recycling.

In 1996, the National Research Council (NRC) released a committee report titled *Use of Reclamation Water and Sludge in Food Crop Production.* The report, following three years of study, examined the adequacy of existing regulations for pathogens, trace metals, organic compounds, effects on soil, crop, and groundwater plus economic, legal and institutional issues. The report concluded that when properly treated, municipal sludge (biosolids) can be both safe and effective for fertilizing food crops. The report declared, AWhile no disposal or reuse option can guarantee complete safety, the use of these materials [reclaimed water and biosolids] in the production of crops for human consumption, when practiced in accordance with existing federal guidelines and regulations, presents negligible risk to the consumer, to crop production, and the environment.@ The NRC report also noted that there have been no reported outbreaks of infectious disease associated with exposure to adequately treated and properly distributed biosolids.

The NRC Committee that developed the report included 14 members with experience in soil and crop science, agricultural engineering, wastewater and solids treatment, soil microbiology, toxicology, ecology, infectious disease, public health, economics, law and other related fields.

Will the land application of biosolids put farm workers health at risk?

There have been no documented instances of negative human health effects from biosolids when treated and applied in accordance with state and federal regulations. In fact, there has been no infectious disease outbreaks among the most exposed and potentially at risk individuals to wastewater and sludge treatment, the wastewater treatment plant employees.

A five-year comprehensive study by the U. S. Environmental Protection Agency, Ohio State University, Ohio Farm Bureau Federation, and the Ohio Department of Health was conducted to determine if land application of biosolids on farmland would increase health risks to rural residents and their livestock. The study consisted of a health effects study of 47 farms using biosolids compared with 46 control farms not using biosolids. This study provided a direct evaluation of human health risks from using biosolids in established land application programs. It included health questionnaire surveys and, more importantly, blood testing of the participating farm families, which provided an objective measure of infection (including sub-clinical infections). The results indicated that the risks of respiratory illness, digestive illness, infections, and general symptoms of illness were not significantly different between families living on farms receiving biosolids and those on control farms.

In an article appearing in the October 1990 issue of *BioCycle*, Rufus L. Chaney addressed the impact of biosolids on the human diet. He concluded that biosolids are extremely safe when used in agriculture as a nutrient source and soil conditioner. Chaney is with the Soil-Microbial Systems Laboratory of Agricultural Research Service, U.S. Department of Agriculture.

Will the land application of biosolids put animal health at risk?
Although studies on the effects of biosolids on wildlife have been difficult to locate, studies on cattle have been conducted. Cattle are a good "indicator" animal for studies on biosolids because they are known to eat fairly large amounts of dirt when grazing.

Cattle that had grazed on the Lowry Landfill site near Denver, CO, were studied for the possible effects of heavy metals and persistent organic compounds. The site had received fairly high applications of biosolids from Denver Metro Wastewater Reclamation District. The study concluded that "cattle grazing on the sludge disposal site were healthy with no signs of pathology. Analysis of various tissues from these cattle did not show elevated levels of metals or persistent organics when compared with cattle not exposed to sewage sludge (biosolids)" (Baxter, 1980)

In the National Research Council 1996 report, *Use of Reclaimed Water and Sludge in Food Crop Production*, the subject of uptake of toxic organic compounds by animals was explored. The report states "Toxic organic compounds present in plant tissues (and soil in the case of pastured animals) may be incorporated into animal tissues. However the low levels of organic compounds to be expected in the aboveground portions of plants growing at land application sites pose little hazard to animals feeding upon them."

The report also discusses the uptake of trace elements by animals exposed to biosolids. Various studies of grazing animals revealed elevated levels of cadmium and other metals in the liver and kidneys, but little or no accumulation within the animal muscle tissue.

Do crops fertilized by biosolids pose a health risk?
No. The U.S. EPA has established safe limits for land application of biosolids constituents, the subsequent growing of crops, and the grazing of cattle. These standards ensure the safety of food products, such as meat and milk, if biosolids are used to grow animal feed.

Can heavy metals in biosolids build up in crops?
Crops grown on land where biosolids have been applied are safe for human consumption. Regulations are very specific concerning the types of food crops that can be grown for periods of time following land application of biosolids. Again, numerous studies by the USDA and others have demonstrated that the consumption of such crops does not pose a threat to human health. Some plants and crops can absorb certain metals from biosolids. However, it is important to note that this plant or animal intake is minimal and research studies have established limits on intake that do not pose a risk to human health.

What type of crops can be grown in fields fertilized with biosolids?
Food processor policies aside, there are five specific regulatory conditions defining the types of crops grown on biosolids fertilized fields. Growers using biosolids will have to plan their crop rotations accordingly.

1. Do not harvest food crops for 14 months after biosolids land application when the crop's harvested portion touches the biosolids-amended soil and the harvested portion is totally above the land surface, when the pathogen reduction level is Class B. Food crops are defined by the U.S. EPA as crops consumed by humans. These include, but are not limited to, fruits, vegetables, and tobacco. Specific crops where the harvested portion may touch the surface include melons, strawberries, eggplant, squash, tomatoes, cucumbers, celery, cabbage, and lettuce (U.S. EPA, 1995).

2. Do not allow animal grazing for 30 days after biosolids land application, when the pathogen reduction level is Class B.

3. Do not harvest food crops for 20 months after biosolids land application when the crop=s harvested portion is below the surface of the biosolids-amended soil <u>and</u> the biosolids remain on the land surface for four months or longer prior to incorporation into the soil, when the pathogen reduction level is Class B. Specific crops where the harvested portion is below the surface include, but is not limited to, potatoes, yams, sweet potatoes, rutabaga, peanuts, onions, leeks, radishes, turnips, and beets.

4. Do not harvest food crops for 38 months after biosolids land application when the crop=s harvested portion is below the surface of the biosolids-amended soil <u>and</u> the biosolids remain on the land surface for less than four months prior to incorporation into the soil, when the pathogen reduction level is Class B.

5. Do not harvest any food, feed, or fiber crops for 30 days after biosolids land application, when the pathogen reduction level is Class B. Feed crops are defined by the U.S. EPA as crops produced primarily for consumption by animals, such as hay or feed corn. Fiber crops are defined by the U.S. EPA as crops such as flax or cotton. Food crops that can be harvested after 30 days after biosolids application include wheat and corn, because the harvested portion does not normally touch the soil.

How long does the land need to remain free of food crops once biosolids have been applied? For example: AIf I plant animal feed this year, will I be able to plant crops for human consumption next season/year?@
If the biosolids are Class A with respect to pathogen reduction and meet the other regulatory standards, it is acceptable to use biosolids and plant food crops next year. If the biosolids are Class B with respect to pathogen reduction and meet the other regulatory standards, it is unlikely that food crops, other than wheat and corn, will be planted the next season after fertilizing the soil with biosolids. The minimum waiting period for harvesting food crops grown above the soil surface yet touch the soil surface is 14-months after biosolids land application. The minimum waiting period for harvesting wheat and corn is 30 days. Growers that decide to incorporate biosolids into their operation will have to plan accordingly.

Why is it necessary to limit public access to biosolids land application sites?
Public access is restricted at sites receiving Class B biosolids. Class B pathogen reduction alternatives significantly reduce but do not eliminate all pathogens. Due to the potential of remaining pathogens, site restrictions must be imposed to allow time for natural processes to further reduce pathogen levels. Studies have shown (example?) that these bacteria quickly die-off once exposed to fresh air, heat, light, and soil. As a safety precaution, the U.S. EPA requires public access to the site be limited for 30 days.

If a land application site is frequently used by the public or has a high potential for public contact, public access must be restricted for 1 year after the Class B sewage sludge is applied.

Why do some food processors not allow the use of biosolids on crops they receive?

Prior to using biosolids to grow crops for human consumption, growers should determine if the use of biosolids is a good business decision for them. Not all food processors ban the use of biosolids on crops they receive, although at this time a majority of processors do prohibit use of biosolids to grow their crops. Some food processors have stated they will void contracts with growers if it is discovered that biosolids have ever been used on the fields covered by the contract. From a recent survey conducted by Sacramento Regional County Sanitation District (SRCSD) there are six reasons why food processing companies find it unacceptable to receive crops grown on biosolids-amended soil.

Market Requirements:	Some grocery markets do not approve of the use of biosolids.
Liability:	There is a perception that the food processor is the only company legally responsible if a problem arises with food that stems from biosolids land application.
Public Perception:	It is possible that an unfounded public scare could occur that would have a significant and long-lasting negative effect on the food processor and growers.
Competition:	Unless all growers and processors use biosolids, it could be used as a marketing strategy by a competitor to gain a competitive advantage.
Farm land value:	There is a perception that the long-term use of biosolids may impair the soil and its future value.
Scientific uncertainty:	There is a perception that it is not yet proven safe to grow food crops on soils receiving biosolids.

Groundwater Issues

How does the land application of biosolids affect groundwater?
When properly applied at agronomic rates, biosolids pose little risk to groundwater quality. However, when applied in exceedance of these rates, potential for groundwater contamination exists. Biosolids, as well as manure and commercial fertilizers, contain essential plant nutrients. When applied at excessive levels, the plants are unable to take up all the available nutrients such as nitrogen, and the extra nitrogen can migrate to the groundwater, usually in the form of nitrate (NO_3^-). In states where water quality monitoring wells are required, the water quality from these wells has demonstrated that when biosolids have been applied at agronomic rates and best management practices followed, no degradation of groundwater quality attributed to biosolids has been observed. Annual monitoring of soil nitrate levels will assist in the prevention of nitrate contamination of groundwater.

Will the metals in biosolids pollute the groundwater?
No. Extensive research over many years has found that trace metals in biosolids strongly adsorb or cling to the soil and organic matter present in biosolids and the native soil. Unless soils are extremely acidic ($pH<5.5$), metal constituents tightly bind to the soil, inhibiting mobility for leaching to groundwater and solubility for plant uptake.

Will pathogens from biosolids contaminate the groundwater?
No. It is extremely unlikely that pathogens from biosolids would end up in the groundwater. During biosolids treatment, the concentration of pathogens is significantly reduced and bacterial levels are usually found to be less than those in manure. It has been found that the pathogens, especially viruses, become very strongly bound to biosolids and are not easily released even after rainfall or irrigation.

Will biosolids pollute the groundwater with trace organic compounds and pesticides?
No. Trace organic compounds and pesticides are rarely found in biosolids prior to land application. These organic compounds are highly volatile. Due to this common property, organic compounds will not be present in the biosolids or soil long enough to be of concern for groundwater quality.

Are monitoring wells needed at application sites?
No. Research over the past 30 years, including the use lysimeters, shallow wells, and deep wells, have found that biosolids pose little risk to groundwater quality. It is not necessary to install wells as long as biosolids are applied at agronomic rates and the site is farmed following normal best management practices.

Surface Water Concerns

How does the land application of biosolids affect surface water pollution?
The land application of biosolids, as with other fertilizers or soil conditioners, does pose a potential threat to surface waters through contaminated runoff. However, due to the unique properties of biosolids, as well as the strict restrictions regarding application, the potential for surface water contamination from biosolids runoff is minimized.

In extreme rainfall events, runoff from agricultural land may occur, carrying sediment, nutrients and other potentially harmful constituents from the biosolids and fertilizer into nearby surface water. A number of studies have been conducted on agricultural land and grassland to address this concern. One such study found that all of the concentrations of the measured constituents in the biosolids runoff waters from grassland were below the EPA drinking water standards and below the recommended levels for livestock water (JEQ, 1995). Other papers observed that each successive runoff event caused a reduction in the pollution potential from both organic-based and inorganic-based fertilizers. The second rainfall event reduced the potential for problem runoff by 55-80% (JEQ, 1984).

Several studies found that the land application of biosolids actually decreased surface water runoff potential. Due to the organic enrichment of biosolids, application has been found to improve soil structure and stability by promoting greater infiltration and protection to the soil surface against rain drop impact and associated erosion (JWPCF, 1979). Researchers found that under high rainfall conditions (about 4 inches per hour on site slopes up to 15%), runoff water quality from biosolids sites was of higher quality than for similar sites receiving manure. Reductions in surface water runoff and erosion were similarly observed and confirmed under simulated severe precipitation conditions on 10% slopes in USFS/City of Albuquerque trials at the Sevilltea LTER Area (ASAE, 1989).

Are there restrictions on irrigation for fields fertilized with biosolids?
No. Standard practice is to till biosolids into the soil after application, with the exception of pastures or other crops that would be damaged by this. In these cases, crop stubble holds the biosolids in place until irrigation and rainfall cause the assimilation of the biosolids into the soil. Under these conditions there are no irrigation restrictions.

How can the surface water runoff from biosolids be controlled?
A combination of efforts can be applied to control surface water runoff at biosolids land application sites. Applying biosolids to the land improves the soil quality, including properties such as water retention capacity and infiltration rate. These two characteristics increase the soil:s capacity to hold water and prevent runoff more effectively than before biosolids application. The organic matter from the biosolids also helps protect the soil against raindrop impact and subsequent erosion. Biosolids are generally applied to flat or gently sloped sites having only a slight potential for surface water runoff.

As an added precaution, it is required that all land application sites incorporate buffer strips from important features. Buffers are non-application areas located within a permitted biosolids application site. Buffer zones vary in width from 5 feet to 500 feet, depending on what the buffer zone is designed to protect. Buffer zone widths are determined by Federal, State, and local regulations, as well as through determinations of specific site suitability.

Does tilling the soil affect biosolids and surface water runoff?
There are several methods of applying biosolids to farm land including subsurface injection of liquid biosolids, surface spreading of biosolids followed by disking, or surface spreading of biosolids under a no-till program. Researchers have found some differences between these different approaches. The least risk potential is with subsurface injection of liquid biosolids, followed by surface spreading of biosolids and disking, followed by surface spreading of biosolids under a no-till program.

What types of soils are best and worst for biosolids?
Biosolids can be successfully applied to virtually any agricultural soil with proper design and operation. However, highly permeable soil (*e.g.*, sand), highly impermeable soil (*e.g.*, clay, although the addition of organic material in biosolids may help reduce impermeability), or poorly drained soils present special situations requiring additional assessment and management.

Permeability (a property determined by soil pore space, size, shape, and distribution) refers to the ease with which water and air are transmitted through soil. Fine textured soils generally possess slow or very slow permeability, while the permeability of coarse-textured soils ranges from moderately rapid to very rapid. A medium textured soil, such as a loam or silt loam, tends to have moderate to slow permeability.

Soils classified as very poorly drained, poorly drained, or somewhat poorly drained by the Soil Conservation Service may be suitable for biosolids application if runoff control is provided. Soils classified as moderately well drained, well drained, or somewhat excessively drained are generally suitable for biosolids application. Typically, a well-drained soil is at least moderately permeable. Effective agricultural site selection with respect to soil suitability can target an ideal soil with the characteristics shown in the table below. The greater the number of properties that depart from ideal and the greater the degree of departure, the more severely limited the soil is for biosolids application. Many of these soils can still be used, but management is required to overcome the limitations.

TABLE OF IDEAL SOIL CHARACTERISTICS

1) Deep, well drained.
2) Medium textured (silt loam, loam or very fine sandy loam).
3) Black to very dark brown surface soil.
4) Brown or yellowish-brown subsoil, no gray matrix, or red/yellow mottles.
5) No restrictive layers (claypan, fragipan, dense till) in subsoil within 40 inches of ground surface.
6) No compaction zone beneath the depth of tillage.
7) Greater than 3% surface soil organic matter content.
8) Moderate to strong surface soil structure, low shrink-swell potential.
9) Available water-holding capacity of 12 inches or more.
10) Moderate to rapid infiltration.
11) Moderately slow to moderately rapid permeability.
12) Level to gently rolling land surface, ~3% slopes.
13) Not on an active floodplain.

Few sites have an "ideal" soil. A soil would be considered ideal for biosolids application if:

C It has the capacity to hold large quantities of water (greater than 12 inches), reducing the potential risk of leaching to groundwater.
C It has moderate-to-rapid infiltration rates when thoroughly wet, so water or liquid biosolids enter the soil rather than moving off-site as runoff.
C The risk of pathogen contamination of groundwater is extremely low, since the soil does not have a seasonal high water table within 1 meter (40 inches) of the soil surface.
C It can handle vehicle traffic without compaction during most of the year.

Source: Cogger, et al. 1993

Metals

What are trace metals?

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Trace metals are part of the fundamental building blocks of the earth. Soils, water, and bedrock naturally contain these elements in varying concentrations. They include metals like arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc. Trace metals are present throughout the environment including soils, food, drinking water, humans, animals, plants, and biosolids.

Do Biosolids contain metals?
Yes, biosolids contain trace concentrations of metals. However, the Part 503 regulations establish allowable concentrations of such metals, as well as appropriate management practices to ensure metals found within land applied biosolids will not endanger human health or the environment.

Where do these metals come from and how can they be controlled?
The trace metals found in biosolids come from both industrial and domestic sources. In the past, industry was a major contributor of trace metals. Upon the development of the Industrial Pretreatment Program, levels of metals in industrial wastewater have decreased significantly.

Domestic metals contributions originate primarily from common household products. The control of residential contributions of trace metals to biosolids is accomplished largely through public education and household hazardous waste collection programs.

Will the use of biosolids contaminate my land with trace metals?
Because trace metals contained in biosolids remain in the soil, their presence at elevated levels was the focus of the earliest, most detailed research in the area of biosolids land application. The U.S. Department of Agriculture and many research scientists throughout the country developed concentration standards for trace metals in biosolids to protect the environment, people, crops, and the animals consuming these crops from overexposure. As a result, the repeated application of biosolids in accordance with the regulations will not result in land becoming unsuitable for any existing or future use.

Land applying biosolids may add lead to the soil. How can this be allowed?
The concentration of lead in biosolids is not significantly different than levels in manures, other recycled organics, or local soils. Recent scientific research has shown that application of biosolids to land that contains high existing levels of lead results in less overall bioavailable lead. The high level of organic matter and relative neutral pH of biosolids immobilize lead. Rather than a concern about adding metals, biosolids offers the advantage of improving the soil quality.

For additional information see, Rufus L. Chaney, Environmental Chemistry Laboratory- USDA-Agricultural Research Service, ARisks Associated With the Use of Sewage Sludge in Agriculture@ Proceedings 15th Federal Convention Australian Water & Wastewater Association, Vol. 1; 1993.

Is there evidence of trace metals buildup in land applied by biosolids?
Trace metals are found in biosolids and a variety of fertilizers and therefore must be monitored. The U.S. EPA extensively studied the metal topic in completing the national regulatory standards for biosolids. EPA concluded that when biosolids contain low levels of metals meeting the regulatory standards, the metals are tightly bound to the soil particles and are not susceptible to movement either into the plant or local waters. EPA also found that the metal-binding capacity of biosolids-amended soils lasts for decades after biosolids application is stopped. Adding biosolids results in a permanent improvement in soil quality. The long-term use of biosolids in accordance with the regulations will raise trace metals concentrations in soil over time but will not affect the wholesomeness or safety of the crops grown.

Are there soil pH standards to ensure metal retention in the soil?

The 503 standards were designed as self-implementing rules to cover all biosolids land application practices. The plant metal uptake values used to establish the regulatory limits included data from acidic, neutral, and alkaline soils representing a broad spectrum of field conditions and safety. EPA concluded that it would be ill advised and unnecessary to require soil pH control due to a variety of mechanisms that offer protection to the environment, crops, and humans. Two major factors include the soil-plant barrier concept developed by USDA researchers and the fact that plant toxicity is a concern at low pH irrespective of the metals source. If a farmer or home gardener desires even moderate success under low pH conditions, they would need to at least add some lime to obtain reasonable crop yields. This results in a self-regulating and protective mechanism.

Pathogens and Vector Attraction Reduction

Pathogens

What are pathogens?
Pathogens are microorganisms that cause disease. Pathogens associated with sewage and biosolids include bacteria, viruses, protozoa, and helminth. Pathogens, often referred to as germs, are very small organisms most often invisible to the unaided human eye.

Bacteria exist everywhere in our environment. Some bacteria are crucial to human life, while some others can be quite harmful, even deadly, to humans and other animals. A well known bacterium is Salmonella, a potentially fatal bacterium often associated with chickens. Viruses are distinctly different from other pathogens because although they will remain virulent for a time, they are unable to reproduce outside the living cell they infect. Viruses are responsible for numerous human diseases including the common influenza. Protozoa can occasionally be found in drinking water, raw or under cooked food (especially pork), or on contaminated food preparation surfaces. Helminth are usually in the form of tapeworms and roundworms, organisms frequently found in dogs, cats, and rats.

Where do pathogens come from?
Pathogens live in essentially all warm-blooded mammals, including all healthy and ill humans, domestic animals, livestock, and wildlife. The pathogens are released by mammals through feces. Wastewater contains pathogens from human feces, collected through sanitary sewers or septic tanks. Pathogens from other animal sources may enter wastewater treatment plants, lakes, streams, or groundwater sources through stormwater runoff.

How are we protected from pathogens?
Pathogenic microorganisms generally do not survive well outside of the body of their host. The ideal environment of these microorganisms matches that of the warm, protected, fluid inside of a mammal. Most pathogens are vulnerable, with little defense against exposure to disinfecting chemicals (e.g. acids or bleaches), heat, light, or dryness. Each pathogen has a unique response and survival time to these hostile conditions. The wastewater treatment process, in addition to Part 503 pathogen restrictions ensure protection from pathogens in biosolids.

Are there pathogens in biosolids?
Yes. Biosolids are a product of the wastewater treatment process. One of the primary functions of wastewater treatment is to protect public health from potentially harmful germs. Many pathogens are destroyed during the collection and biological treatment of wastewater, and most of the remainder through the solids treatment process. It is important to note that pathogens cannot multiply outside of living hosts. For example, the AIDS virus is transferred only through intimate body contact with transfer of body fluids and the virus has never been found to survive the wastewater treatment process.

How are biosolids treated to kill pathogens?
The presence of pathogens in wastewater and the biosolids resulting from wastewater treatment requires treatment of these solids to reduce any remaining pathogens to a safe level before beneficial reuse. Municipal wastewater treatment includes a wide variety of processes to kill germs. The resulting products—biosolids—are then safely recycled as organic fertilizer, soil enhancements, or construction materials.
Depending on the amount of treatment received by the biosolids, the resulting products are classified as either Class A biosolids or Class B biosolids. Class A biosolids are treated to a greater degree than Class B biosolids and are safe for direct human contact (e.g. bagged compost). Class B biosolids are treated to a safe level but do require compliance with land and crop use restrictions.

Commonly used treatment methods include:

1. Digestion- anaerobic (without oxygen) or aerobic (in the presence of oxygen) breakdown of wastewater solids at elevated temperatures that kill pathogens.
2. Composting- aerobic breakdown of wastewater solids at elevated temperatures that kill pathogens. Composting combines biosolids with wood chips, bark, and other organic matter.
3. Heat Drying- use of heat to dry the biosolids (elevated temperatures and lack of moisture effectively destroy pathogens).
4. Chemical Stabilization- use of alkaline (high lime) or other chemicals to create an environment that destroy pathogens.

Is the absence of fecal coliform a reliable indicator of the absence of other pathogens?
Yes. Although there is a great diversity of germs in the environment, it is possible to monitor a few germs that indicate the presence or absence of fecal matter. Fecal coliform bacteria are one of several bacteria used to judge the sanitary quality of water, wastewater, and biosolids. Monitoring all pathogenic microorganisms is impractical due to very large number of different germs. Not all pathogens respond the same way in the environment and therefore it is important to evaluate a range of pathogens.

What data are available regarding health related problems relating to sludge application?
The National Academy of Sciences= National Research Council report on AUse of Reclaimed Water and Sludge in Food Crop Production@ (1996), AThere have been no reported outbreaks of infectious disease associated with a population=s exposure- either directly or through food consumption pathways- to adequately treated and properly distributed reclaimed water or sludge applied to agricultural land.@ The report also notes that since there are many sources of infectious disease agents other than the use of reclaimed water or biosolids, such as prepared food and person-to-person contact, the potential added exposure to pathogens from the proper recycling of these materials is Aminuscule compared to our everyday exposure to pathogens from other sources.@

What is AIDS?
AIDS stands for Acquired Immunodeficiency Syndrome. AIDS is the disease that results from Human Immunodeficiency Virus (HIV) infection. HIV infection occurs when the virus invades a human and attacks and destroys T_4 cells in the bloodstream. AIDS is the disorder of the human immune response system caused by this depletion of the T_4 cells. Losing T_4 cells means that the person is not able to fight off other infections, thus the concept of acquiring a deficiency in disease immunity.

T_4 cells are an important type of cell in the normal immune response system of humans. The complex human immune system uses two types of cells to detect and fight disease. The T-cells are the controllers and regulators of the immune system (managers) while the B-cells are the factories producing antibodies (workers). Antibodies are human=s natural defense mechanism against bacteria or their toxins. In the case of AIDS, the depletion of T_4 cells causes the immune system to not detect a potential disease-causing bacteria or toxin, nor trigger B-cell production of disease fighting antibodies. The blood stream is left defenseless against infection.

Can AIDS be transmitted by biosolids?
No. Scientists have conducted thousands of tests on wastewater, biosolids, raw feces, and urine attempting to find HIV. No HIV has ever been recovered from samples during these tests. Scientists have even seeded HIV directly into these samples and discovered that HIV cannot survive. Scientists have learned that HIV cannot survive in tap water, wastewater, or biosolids.

It is helpful to think of HIV as a parasite. It cannot survive or reproduce without a host cell, specifically a limited number of cells in human blood containing one particular protein. Researchers have learned that HIV loses its infectivity within hours of leaving the body. Research shows the virus expires very quickly after introduction to water, and that it does not regain its potency. Neither feces or urine, the human wastes most common in sanitary sewer systems, appear to carry HIV. The human body fluids known to carry relatively high concentrations of the virus, blood, semen, and vaginal fluids, are released in small quantities to sewers and are diluted by much larger flows of water. Commercial and industrial materials in the sewers are toxic to HIV, and are likely to destroy the virus. The average sanitary sewer, wastewater treatment facility, and biosolids land application operation provides an environment so hostile to even the most persistent virus that survival is virtually impossible.

Can biosolids carry AIDS to animals which might transmit the disease to humans?
No. There is virtually no chance that HIV would survive the trip from the household or other sewer user to the wastewater treatment plant. If HIV did survive, the chances of survival end with the treatment, storage, and transportation of the wastewater and biosolids. Animals grazing or passing through biosolids land application sites will not come in contact with HIV. HIV cannot survive outside the host body for more than 72 hours and is infectious for even shorter time periods. A typical biosolids component has existed for over 550 hours from the time it is released by a human until it arrives at a biosolids land application site.

Can biosolids cause AIDS?

Summary:
It has been demonstrated that conventional wastewater and biosolids treatment process are capable of reducing the populations of pathogens in general, and viruses in particular, to levels which are considered to be safe by various public health agencies. Demonstration of the efficiency of conventional treatment processes in destroying HIV has not been made due to the apparent inability of HIV to survive conditions typical of domestic sewage.

Issue:
Concerns over the pathogenicity of biosolids are frequently raised by landowners, producers, and the public in discussions of land application. Biosolids may contain a variety of viable pathogens dependent upon the type and efficiency of biosolids treatment processes. Federal requirements at 40 CFR Part 503 identify biosolids treatment requirements which have been developed to reduce exposure to pathogens in biosolids to levels that are safe. But do these criteria adequately address disease-causing organisms which have recently become public health issues, specifically the AIDS virus?

Analysis:
The presence of various disease-causing organisms in sewage has been widely documented. Pathogens in sewage may include bacteria, viruses, and parasitic protozoa and helminth. Pathogens are present in varying amounts in raw sewage, dependent upon the overall health and age of the population served by the wastewater treatment facility. Wastewater and biosolids treatment processes destroy pathogens to varying levels. State and federal regulations address issues of potential disease transmission through biosolids treatment processes and by requiring monitoring to document pathogen destruction. Biosolids may be treated to one of two levels of pathogen destruction. Treatment to Class A requirements produces a biosolids in which pathogen populations are reduced to minimal levels. As such, the risk of contagion is also minimal, and is indistinguishable from the indigenous population. Class A biosolids, assuming applicable contaminant limitation are also met, may be used without the imposition of additional regulatory restrictions. Biosolids treated to Class b levels may contain limited number of pathogenic organisms. Class B biosolids must therefore be used in accordance with regulatory criteria applicable to control of public access to the application site and cropping and/or grazing restrictions. These restrictions are

intended to assure that any risk of disease transmittal associated with the use of Class B biosolids is minimized.

It is important to note that epidemiological studies of the health of workers at municipal wastewater treatment plants, as well as people living in areas surrounding treatment facilities, have demonstrated that there is no increased risk of disease transmission associated with proximity to biosolids. These findings are supported by studies of the health of families living on farms where biosolids are used. Nonetheless, concerns over Acquired Immune Deficiency Syndrome (AIDS) have caused health officials to re-evaluate the adequacy of existing regulatory controls in safeguarding both wastewater professionals as well as the public against the possibility of biosolids-related exposure to the AIDS virus.

Transmission of Human Immunodeficiency Virus (HIV), the causative agent of AIDS, has been shown to result from sexual contact, from sharing of needles by intravenous drug users, from transfusion of contaminated blood or blood by-products, and perinatally, by mother to fetus. HIV is a blood-borne virus which cannot multiply outside of a viable host cell. Transmission of the virus from an infected individual therefore requires that either blood or bodily fluids containing blood cells or T-cells, which are blood like cells found in semen, be introduced into the receptor bloodstream. There is a potential for blood or other contaminated material to be discharged to the sanitary sewer system. The issues which therefore must be addressed include the concentration and survivability of the virus in wastewater, as well as the efficiency of the wastewater and solids treatment precesses in inactivating any virus which might be present.

As noted earlier, HIV cannot replicate itself outside of an infected host. Therefore, there is no potential for multiplication of the virus once it is discharge into the wastewater collection system. The Center for Disease Control (CDC) reports that HIV in infected individuals is found at concentrations of 1 to 1,000 virus/ml blood. This compares to 1,000,000,000 virus/ml blood in individuals infected with the Hepatitis B virus (HBV), a similar blood-borne pathogen. The potential quantity of HIV which may be discharged to a sanitary sewer system is therefore much lower than for similar blood-borne viral diseases. The absence of any instance of water-borne hepatitis infection among wastewater workers, despite exposure to that virus in much greater concentration than HIV, has led the CDC to conclude that there is no possibility of water-born transmission of the AIDS virus.

The ability of HIV to survive in wastewater appears to be minimal. Researchers have demonstrated that HIV, when seeded into a non-chlorinated wastewater sample and cultured under laboratory conditions, may survive for a period of some 12 to 48 hours. The research suggests, however, that although the virus may survive in waster for a period of time, it does not retain its infectivity. HIV and other viruses are enclosed in a complex protein/lipid envelope which must remain intact for the virus to remain infectious. Researchers believe that unfavorable osmotic pressure caused by dissolved solids in wastewater disrupts the membrane, thereby causing the virus to lose its capability to infect target cells. Additionally, both chlorine and ammonia, chemical constituents typically present in tap water and wastewater, respectively, have been demonstrated to be effective virucides. Moreover, the virus as never been recovered from wastewater samples into which it has not been artificially introduced. Researchers have recovered viral nucleic acid fragments in wastewater which have tentatively been identified as HIV-specific RNA or DNA sequences. This analytical method, polymerase chain reaction (PCR) amplification, has not detected similar fragments in biosolids. The nucleic acid sequences detected do not represent the presence of viable HIV. Again, no intact HIV have been recovered from either raw sewage or from biosolids. This research further supports CDC=s contention that wastewater treatment professionals, as well as members of the public who may contact wastewater or biosolids, are not at risk of contracting AIDS as a result.

The apparent inability of HIV to survive in wastewater under typical conditions precludes any demonstration of the efficiency of wastewater or biosolids treatment precesses in inactivating HIV. Other virus, however, are often present in raw primary and secondary sludge. The efficiency of biosolids treatment processes may be quantified by monitoring those pathogens.

There are a variety of treatment processes available which, when operated in compliance with federal and state regulatory criteria, produce biosolids which are essentially pathogen-free. In the Rocky Mountain Region, composting is the most widely utilized treatment option capable of achieving this level of pathogen reduction. Pathogen virus are in capable of surviving the elevated temperature attained in the composting process. Other options may include either air drying for an extended period or accelerated drying by heating the biosolids. Desiccation of the virus is also an effective method of viral inactivation. Increasing the pH of the biosolids with lime or other alkaline material has also been demonstrated to be an efficient method of eliminating virus from biosolids.

Class B biosolids treatment processes typically involve either aerobic or anaerobic digestion. Aerobic digestion is, under certain circumstances, capable of producing a Class A biosolids product. This requires that the digester be designed to operate at temperatures which are higher than typical for this type of system. This kind of treatment, known as autothermal aerobic digestion, is not currently in use. Typical aerobic and anaerobic digestion is capable of producing a 0.5 to 2.0 log reduction in virus densities. This compares to the 4.0 log reduction that a properly operated Class A system may achieve. Lagoon systems will typically exhibit the lowest efficiencies for common wastewater treatment plants. Monitoring of indicator organisms in lagooned biosolids, however, typically indicated reductions in pathogen populations to Class B levels. It is important to note the indicator organisms are selected, in large part, because their susceptibility to removal or destruction during treatment is less than that of t pathogenic organisms. The use of indicator organisms as indicators of pathogen destruction efficiency is therefore a conservative approach because pathogen destruction will always be underestimated.

Although there has never been a documented instance of disease transmission resulting from biosolids use, even prior to the imposition of rigorous treatment requirements, there remains the need to impose additional use requirements on Class B biosolids products. Federal and state regulations therefore require a variety of site management restrictions that ensure environmental stresses after the biosolids are applied to land will destroy any remaining viable virus or other pathogen.

Vector Attraction Reduction

What are vectors?

Vectors are organisms that carry pathogens from one host to another. Pathogens in biosolids may pose a disease risk when in contact with humans or other susceptible hosts. Vectors include flies, mosquitoes, rodents, pets, and birds. Vectors can transmit pathogens to humans through direct contact such as bites.

Will biosolids attract flies, rats, or birds?

Generally biosolids do not provide an attractive environment for flies, rats, or birds. These creatures are attracted to a food supply, pungent odors, a comfortable habitat, or a water source. Regulatory standards published by the U.S. EPA require significant treatment and reduction of volatile solids and odor-causing components in biosolids prior to its land application. Special management practices are required for land application of certain types of biosolids to prevent any additional risk of attracting vectors. Meeting these standards minimizes favorable conditions for vectors and protects public health and the environment.

How are biosolids treated and managed to lessen vectors?

The U.S. EPA requires use of one of ten techniques to reduce vector attraction prior to land application of biosolids. These treatment and management operations parallel the processes used in reducing pathogens. The treatment options include aerobic digestion, anaerobic digestion, composting, lime stabilization, heat or air drying. Management operations include injecting or disking biosolids into the soil to prevent any exposure of the material to likely vectors.

Biosolids produced by the Sacramento Regional County Sanitation District are treated by anaerobic digestion to satisfy the U.S. EPA vector attraction reduction requirements. The digestion process typically reduces the volatile solids content of the Sacramento County biosolids by 50 percent or more, well in excess of the 38 percent minimum reduction required by the U.S. EPA.

Trace Organics:

What are trace organics?

Trace organics are chemicals based on carbon compounds. Most organic chemicals are very complex and highly technical. Some example classes of organic chemicals that may appear in wastewater are solvents, paints, pesticides, chorine disinfection byproducts, and polychlorinated biphenyls (PCBs). Trace organics such as halogenated hydrocarbons, benzo(a)pyrenes, ditnethyl nitrosamines and non-halogenated organic pesticides appear to pose the greatest risk to human health. The U.S. EPA has identified a number of organic chemicals with potential toxicity to humans, animals, plants and the environment. This list of compounds, originated in 1976, is known as the Priority Pollutants. Many of the chemicals of the Priority Pollutant list have been banned from manufacture or use in the United States.

Where do organic chemicals in wastewater come from?

Organic chemicals found in wastewater come from both industrial and domestic sources. Organic chemicals are widely used throughout the industrial community. However, often times these organic chemicals are removed before entering into the wastewater collection system, due to the Industrial Pretreatment Program. The presence of many potentially toxic organic chemicals has also greatly diminished due to bans or limitations enacted by the U.S. EPA. For example, the EPA has banned PCBs and certain pesticides, and has placed strict limitations on the emission of dioxins into the environment. Industrial sources of organic chemicals in wastewater include manufacturing for use in agriculture or horticulture, incomplete burning of oil-based fuels, water and wastewater disinfection and solvents. Homeowners can also contribute to organic chemicals in wastewater. Paints, solvents, cleaners, lawn fertilizers and pesticides are all domestic sources of organic chemicals that end up in the wastewater collection system.

Are there trace organics in biosolids?

Yes, trace organic chemicals may be found in biosolids. The occurrence of these chemicals in biosolids depends on the number and kind of industries and homeowners discharging wastes into the sewer systems. Studies have shown that the occurrence of harmful trace organics in biosolids, such as Priority Pollutants, is very rare, generally at levels not even detectable by laboratory analysis.

Are biosolids toxic or hazardous to health?

No. Biosolids must be non-hazardous if applied to lands or put into compost. There is no evidence that suggests that land application of properly treated and managed is hazardous to health. In addition, there have been no reported outbreaks of foodborne disease linked to biosolids in the United States.

There are a few main mechanisms protecting public health and the environment from potential risk due to organic chemicals. The first mechanism is regulatory controls. Because of regulatory requirements, the concentration of organic chemicals in biosolids are extremely low, and often times undetectable by laboratory analysis. The other mechanisms are related to the fate and transport of trace organics when biosolids are land applied. Within hours of application, many organic compounds will be broken down or destroyed by volatilization, biodegradation, chemical oxidation, or photolysis. Other organics may become immobilized by adsorption to soil particles, greatly minimizing the potential for plant uptake or surface and groundwater contamination.

For information on scientific studies relating to organic chemicals in biosolids, see the National Research Council's "Use of Reclaimed Water and Sludge in Food Crop Production", a report published in 1996.

What becomes of strong household cleaning compounds and products like drain cleaner?

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When household cleaning products and other compounds are released, several events occur throughout the transport, treatment and disposal processes. These chemicals are released into the sewer system in comparatively small quantities and are diluted with the other wastewater flowing to the treatment plant. Throughout the transport system, many organic chemicals are broken down during passage. Upon entrance into the treatment system, wastewater, residual solids, and any organic chemicals go through an extensive series of treatment steps. These treatment steps can include aerobic and anaerobic processes, agitation, oxygenation, and settling, all of which contribute to the destruction of the trace organics. By the end of the transport and treatment process, very few, if any, organic chemicals remain in the biosolids. If the biosolids do contain trace organics, the potentially toxic effects of these compounds will be mitigated upon land application.

DIOXINS:

WHAT ARE DIOXINS AND ARE THEY IN BIOSOLIDS?

DIOXIN IS A COLORLESS, ODORLESS ORGANIC COMPOUND CONTAINING CARBON, HYDROGEN, OXYGEN AND CHLORINE. DIOXIN IS A GENERIC TERM USED TO DESCRIBE A BROAD FAMILY OF CHEMICALS THAT DIFFER FROM ONE ANOTHER BY THE LOCATION, AND NUMBER OF CHLORINE ATOMS IN THE MOLECULE. THERE ARE 210 POSSIBLE VERSIONS OF THE COMPOUND IN THE DIOXIN FAMILY.

DIOXINS ARE PRODUCED DURING THE MANUFACTURE, COMBUSTION, OR DEGRADATION OF PRODUCTS CONTAINING CHLORINE. THE LARGEST SINGLE SOURCE OF CHLORINE USE IN MANUFACTURING IS IN THE PRODUCTION OF POLYVINYL CHLORIDE PLASTICS (PVC). OTHER SOURCES OF DIOXIN INCLUDE CHLORINATED SOLVENTS, PESTICIDES, INORGANIC CHEMICALS, ORGANIC CHEMICALS, METALLURGY, AND VEHICLE FUEL. IN A RECENT ANALYSIS OF THE DIOXIN EMISSIONS IN THE SAN FRANCISCO BAY AREA, IT WAS REVEALED THAT 69% OF DIOXIN EMISSIONS WERE FROM VEHICLES, 15% WERE FROM RESIDENTIAL WOOD BURNING, AND 16% FROM ALL THE REMAINING MANUFACTURING AND INCINERATION OPERATIONS.

BECAUSE DIOXINS ARE LARGELY PRODUCED BY COMBUSTION, THEY ARE PRESENT THROUGHOUT THE ENVIRONMENT. MOST RESIDENTIAL AND AGRICULTURAL SOILS, FOR EXAMPLE, CONTAIN DETECTABLE LEVELS OF DIOXINS. DIOXINS ARE ALSO FOUND AT EXTREMELY LOW CONCENTRATIONS IN BIOSOLIDS, OFTEN COMPARABLE TO BACKGROUND DIOXIN LEVELS IN SOILS. DIOXINS ARE NOT CREATED IN THE WASTEWATER OR BIOSOLIDS TREATMENT PROCESSES. HOWEVER, THE PROCESS OF TREATING WASTEWATER COLLECTS DIOXINS ALREADY EXISTING IN THE ENVIRONMENT FROM OTHER SOURCES.

PH CHANGES AND SALINITY CONCERNS:

WILL THE LAND APPLICATION OF BIOSOLIDS CAUSE EXCESSIVE SALT ACCUMULATION IN THE SOIL?

THERE HAVE BEEN CONCERNS AMONG AGRICULTURAL PRODUCERS REGARDING THE EFFECTS OF BIOSOLIDS ON SOIL SALINITY. SIMILAR TO IRRIGATION AND FERTILIZER APPLICATION, BIOSOLIDS APPLICATION CAN CAUSE EXCESS SALINITY IN THE SOIL. UNLESS SALTS ARE REMOVED FROM THE ROOT ZONE OF THE CROPS BY PLANTS OR LEACHING, THEY ACCUMULATE AND CAN REACH LEVELS THAT WILL PREVENT GROWTH OF PLANTS, EXCEPT FOR THE MOST SALT TOLERANT. BECAUSE OF THE POTENTIAL FOR SALT BUILDUP, IT IS ESPECIALLY IMPORTANT TO APPLY BIOSOLIDS AT AGRONOMIC RATES. NUMEROUS STUDIES BY THE U.S. EPA AND USDA HAVE SHOWN THAT SALINITY IMPACTS CAN BE CONTROLLED WHEN AGRONOMIC RATES AND GOOD LAND MANAGEMENT TECHNIQUES ARE FOLLOWED.

WILL THE LAND APPLICATION OF BIOSOLIDS CAUSE PH CHANGES IN THE SOIL?

BIOSOLIDS REFERENCE SHEET

Concerns have been expressed by the agricultural community regarding the pH effects of applying biosolids. The soil pH is a measurement of degree of soil acidity or alkalinity. A neutral soil pH, between 6.0 and 7.0 is the most commonly desired pH because nutrient availability tends to be at a maximum. Highly acidic soils (pH less than 5.0) can cause some elements to become toxic to plants, such as iron and aluminum. Acidic soil has also been found to cause magnesium deficiencies in various crops. Highly alkaline soils (pH higher than 9.0) can create high sodium contents that restrict plant growth as well as inhibit the plant availability of nutrients such as phosphorus. To avoid potentially harmful changes in soil pH, it is necessary to apply biosolids at agronomic rates. The U.S. EPA and USDA have conducted numerous studies that show that potential pH impacts can be controlled with proper application of biosolids and good land management techniques.

Rangeland Application

What are the effects of biosolids application on rangeland?

Decades of grazing and wind erosion have left the nation's rangelands deficient in nutrients and organic matter. The land application of biosolids on rangeland provides the opportunity to replenish the soil, enhancing forage production, groundcover, water retention and reducing surface water runoff. Surface application without incorporation is most often advised because it does not disturb the existing plant community's root zone and minimizes disturbance to the surface and soil structure.

Increased vegetative productivity

The land application of biosolids on rangeland increased the vegetative productivity of the land. Biosolids have been applied to rangeland in Colorado and New Mexico at rates ranging from 0.0 to 90.0 Mg/ha (dry-weight basis). The studies reported increased vegetative productivity as a result of biosolids application. The studies in New Mexico reported the most favorable vegetative growth at rates of 22.5 and 45 Mg/ha. One study reported a two-to-three-fold increase in vegetative growth at these rates. The Colorado studies reported enhanced forage production occurring at 4.5 Mg/ha with maximum vegetative growth at 11 Mg/ha.

In studies conducted in Fort Collins, Colorado, the vegetative response was similar for the plots that received dewatered biosolids and composted biosolids, and biomass and canopy cover generally increased with increasing application rates. The metal concentrations in plant tissues remained within normal ranges and well below the toxic levels for plants and livestock. Potential changes in the composition and species of rangeland vegetation were observed. The Fort Collins studies showed that the four dominant species responded differently to increasing biosolids application rates. Blue grama and western wheatgrass increased in biomass and canopy cover with increased application rates. Buffalo grass and fringed sage showed a decrease in cover and biomass, although not always significantly. Other studies show an increase in species diversity with biosolids application. In New Mexico, the blue grama forage production increased two-to-three fold, while snakeweed decreased with the application of biosolids.

Groundwater Impacts

As with all fertilization, nitrate is the most mobile and abundant and has the greatest potential for reaching the groundwater. Since rangeland is not irrigated, natural precipitation provides the driving force. A study in New Mexico evaluated seasonal soil water changes and assessed the potential for leaching. In the study, it was observed that the soil moisture content did not significantly increase at a depth greater than 161 cm and remained well below the soil's water retention capacity. The study concluded that, baring additional inputs such as flooding, leaching would not likely occur below 1.5 m. The Fort Collins studies showed that application of biosolids initially caused higher moisture content in the shallow root zone.

Surface Water Impacts

Studies in Fort Collins and New Mexico demonstrated that surface runoff from biosolids application sites can be safely managed. The most sever test was in Fort Collins. The Fort Collins studies used a rainfall simulator to imitate a severe rainfall event shortly after a surface application of biosolids. The test plots were on 8 percent and 15 percent slopes and samples were taken immediately at the edge of the test plot. This study found that an estimated application rate of 1.5 dry tons/acre would not create any potential NO_3-N or trace element pollution problems. A study performed at the Sevilleta Long-Term Ecological Research Area near Socorro, New Mexico, demonstrated that surface runoff and consequent solid losses were eliminated when range test plots, with slopes of 6 percent and 10 percent, were surface treated with biosolids at a one-time application of 4.5 dry Mg/ha. Even intense simulated rainfall failed to yield runoff from the test plots, suggesting that improved retention of precipitation may be a dominant factor in biosolids rangeland reclamation.

Another study conducted to evaluate the runoff water quality from pasture where biosolids and several different sources of animal manure were surface-applied clearly demonstrated that for a number of components (e.g.,. nitrogen, suspended solids, total phosphorus) the biosolids exhibited the least overall potential for surface water contamination; in fact, the runoff water from biosolids was very similar to the analysis of the control (no treatment) samples. (JEQ, 1984)

OTHER ENVIRONMENTAL EFFECTS

WIND BLOWN EFFECTS:

CAN BIOSOLIDS BE BLOWN OFF THE LAND, AFFECTING ADJACENT PROPERTIES AND PEOPLE?

The generation of windblown dust is not uncommon among agricultural practices. Standard operations such as tilling often generate dust, regardless of whether biosolids have been applied or not. The distance the dust travels is simply a function of the soil type and wind velocity. The U.S. EPA has evaluated the risks associated with windblown soil and dust from biosolids-amended soils and has determined that the use of biosolids does not increase risk to farm workers or neighbors over traditional agricultural practices.

It is possible that extremely dry, powdery biosolids could blow off the site during the application process. The only likely scenario where this could occur assumes that biosolids are less than 25% moisture, the biosolids are in powder form rather than pellets, granules, or compost, and land application occurs when winds are blowing in excess of 25 miles per hour.

CAN TILLING THE SOIL WORSEN WIND EROSION OF SOIL AND BIOSOLIDS?

On a well-managed farm, tilling the soil and biosolids will not worsen soil erosion concerns. Severe wind erosion of soil is caused when the soil is not properly managed resulting in bare, dry soil. Adding biosolids to soil over time will increase the organic content of the soil and its moisture holding capacity. These improved soil characteristics significantly reduce the potential for dust or soil erosion.

WILDLIFE EFFECTS:

WILL WILDLIFE AND MIGRATING BIRDS BE AFFECTED BY THE LAND APPLICATION OF BIOSOLIDS?

No. Compliance with Federal and State laws and regulations ensure that fish and wildlife, including migrating birds and any endangered or threatened species, will not be adversely impacted from biosolids land application. Biosolids are not allowed to enter waterways so no impact could occur to fish or water fowl. Biosolids application occurs primarily in agricultural settings such as corn, cotton oat, or barley fields, where wildlife use is less than in natural habitat. The risk assessment developed by the U.S. EPA considered effects to wildlife in the development of standards.

ODORS:

DO BIOSOLIDS CAUSE ODOR PROBLEMS?

As with the application of animal manures, odors can results from the land application of biosolids. However, the odor is generally much milder than that associated with sheep, swine, cattle or poultry manures. Most often, when the biosolids have been thoroughly digested and aged at the wastewater treatment plant, the odor is that of moist soil. On occasions when biosolids have been rushed through the treatment process, a more obnoxious odor may be observed. This odor may smell sour, have an ammonia-like smell, or smell like a swamp. It also is not uncommon for dewatered biosolids to have a fishy scent, due to a polymer added during the dewatering process.

Where does this odor come from?

Odors are derived from volatile complex chemical compounds. The substances readily evaporate at normal temperatures and pressures, releasing a gas that is detected by our sense of smell. The odors associated with biosolids are a result of the vaporization of chemicals such as carbohydrates, proteins, cellulose and sugars. As these compounds decompose, odors of various types and strengths are released throughout the process. Compounds such as carbon, nitrogen, oxygen, hydrogen and sulfur are often contained in the gaseous releases.

Odor problems associated with biosolids usually occur at the time of land application. The emissions have been found to decrease significantly within 15 minutes of the application, and should completely dissipate by a day or two after application. The odor may reoccur for a day or two after the first irrigation or rainfall event. Odor problems resulting from land application can be greatly reduced through practices such as tilling or incorporation of the biosolids.

Biosolids Q & A was compiled by Jana Lang, Environmental Engineer, EPA Region VIII.

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SECTION 2.7 C PATHOGEN AND VECTOR ATTRACTION REDUCTION METHODS

In 1979, the development of 40 CFR Part 257, Criteria for Classification for Solid Waste Disposal Facilities and Practices, addressed the concerns of pathogen and disease vectors in sewage biosolids. Appendix II of Part 257 established specific treatment processes for pathogen and vector attraction reduction. These processes were referred to as "Processes to Significantly Reduce Pathogens" (PSRP) and "Processes to Further Reduce Pathogens" (PFRP). In addition to PSRP and PFRP processes, 40 CFR Part 503 Subpart D establishes additional methods and requirements for adequate pathogen and vector attraction reduction techniques.

For a complete understanding as to why and how pathogen and vector attraction reduction methods are necessary, refer to *Technical Support Document for Reduction of Pathogens and Vector Attraction in Sewage Sludge* (EPA 822/R-93-004, Nov. 1992). A few points can be made here. The pathogens fecal coliform bacteria, enteric viruses, Salmonella, and helminth ova were selected because although there are many pathogens present in sewage biosolids, usually a surrogate organism can be identified more easily. The surrogate organism is then used as an indication for the remaining similar organisms. This is the case for the four pathogens selected for Part 503.

The fact that diseases are associated with vectors is well-known, and ". . . the transport of vectors can play a major role in disease transmission. The health risk to humans and animals posed by this transmission route can be reduced substantially by reducing the attractiveness of sewage sludge to vectors."[1] Therefore, multiple methods for the reduction of vector attraction have been developed and incorporated into Part 503.

In terms of the regulations in 40 CFR Part 503, pathogen and vector attraction reduction can be accomplished by any of the following summarized methods. Alternatives are presented on the following page; the complete requirements are presented in Part 503 Subpart D, as well as a listing of PFRP and PSRP equivalents.

The following is merely a summary of pathogen and vector attraction reduction methods and is intended to be a quick reference guide to the available options. You are strongly encouraged to read the entire Subpart DCPathogen and Vector Attraction ReductionC40 CFR Part 503 for detailed explanations of the following.

PATHOGEN REDUCTION OPTIONS

Class A Pathogen Reduction

Alt 1 - Time and temperature - Biosolids temperature should be maintained for a prescribed period of time according to the guidelines in Appendix B.

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[1] *Technical Support Document for Reduction of Pathogens and Vector Attraction in Sewage Sludge.* (EPA 822/R-93-004, Nov. 1992), p. 10.

Alt 2 - pH, temperature and time - The pH of the biosolids is raised to above 12 for a period of at least 72 hours and the biosolids must be above 52EC for at least 12 hours during this period.

Alt 3 - One-time demonstration correlating pathogen levels and operating parameters - If the biosolids are analyzed before the pathogen reduction process and are found to have densities of enteric virus <1 pfu per 4g of TS and viable helminth ova <1 per 4g of TS, the biosolids are considered Class A until the next monitoring episode. If the biosolids are analyzed before the pathogen reduction process and found to have densities of enteric virus $1 pfu per 4g of TS or viable helminth ova$1 per 4g of TS, and tested again after processing and found to meet the same levels, then the biosolids are considered Class A (assuming the operating parameters for the pathogen reduction process are monitored and shown to be consistent with the values or ranges of values documented at all times).

Alt 4 - Concentrations of enteric viruses and helminth ova - If the biosolids are not analyzed before pathogen reduction processing for enteric viruses and viable helminth ova, then the density of enteric viruses must be <1 pfu per 4g of TS and the density of viable helminth ova must be <1 per 4g of TS, **or**

Alt 5 - Processes to further reduce pathogens (PFRP) - Biosolids must conform with one of the following PFRP options:

1. *Composting* - Using either the within-vessel composting method or the static aerated pile composting method, the temperature of the biosolids is maintained at 55EC or higher for three days. Using the windrow composting method, the temperature of the biosolids is maintained at 55EC or higher for 15 days or longer. During this period, a minimum of 5 windrow turnings is required.
2. *Heat drying* - Biosolids are dried by direct or indirect contact with hot gases to reduce the moisture content of the biosolids to 10% or lower. Either the temperature of the biosolids particles exceeds 80EC or the wet bulb temperature of the gas in contact with the biosolids as the biosolids leave the dryer exceeds 80EC.
3. *Heat treatment* - Liquid biosolids are heated to a temperature of 180EC or higher for 30 minutes.
4. *Thermophilic aerobic digestion* - Liquid biosolids are agitated with air or oxygen to maintain aerobic conditions and the mean cell residence time of the biosolids is 10 days at 55Eto 60EC.
5. *Beta ray irradiation* - Biosolids are irradiated with beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature (*ca*. 20EC).
6. *Gamma ray irradiation* - Biosolids are irradiated with gamma rays from certain isotopes, such as Cobalt 60 and Cesium 137, at room temperature (*ca*. 20EC).
7. *Pasteurization* - The temperature of the biosolids is maintained at 70EC or higher for 30 minutes or longer.

Alt 6 - Equivalent to PFRP - Biosolids must be treated in a process that is equivalent to PFRP, as determined by the permitting authority.

In addition, all six alternatives include pathogen levels for fecal coliform and Salmonella.

Class B Pathogen Reduction

Alt 1 - Density of fecal coliform - At least seven biosolids samples must be collected at the time of use or disposal and analyzed for fecal coliform during each monitoring period. The geometric mean of the density of fecal coliform in the samples collected must be <2,000,000 MPN/g of TS per 2,000,000 CFU/g of TS.

Alt 2 - Processes to significantly reduce pathogens (PSRP) - The biosolids must conform with one of the following PSRP options:

1. *Aerobic digestion* - Biosolids are agitated with air or oxygen to maintain aerobic conditions for a mean cell residence time and temperature between 40 days at 20EC and 60 days at 15EC.
2. *Air drying* - Biosolids are dried on sand beds or on paved or unpaved basins for a minimum of three months. During two of the three months, the ambient average daily temperature is above 0EC.
3. *Anaerobic digestion* - Biosolids are treated in the absence of air for a mean cell residence time and temperature between 15 days at 35EC to 55EC and 60 days at 20EC.
4. *Composting* - Using either the within-vessel, static aerated pile, or windrow composting methods, the temperature of the biosolids is raised to 40EC or higher for five days. For four hours during the five days, the temperature in the compost pile exceeds 55EC.
5. *Lime stabilization* - Sufficient lime is added to the biosolids to raise the pH to 12 after two hours of contact.

Alt 3 - Equivalent to PSRP - Biosolids must be treated in a process that is equivalent to PSRP, as determined by the permitting authority.

VECTOR ATTRACTION REDUCTION (VAR) OPTIONS

VAR Methods for Preparers of Sewage Biosolids

Alt 1 - 38% volatile solids reduction (VSR) - Mass of volatile solids (VS) is reduced by 38% or more.

Alt 2 - Anaerobic digestion - If 38% VSR cannot be achieved for anaerobically digested biosolids, VAR can be demonstrated by further digesting a portion of the biosolids in a bench-scale unit for an additional 40 days at 30E to 37EC or higher and achieving a further VSR of less than 17%.

Alt 3 - Aerobic Digestion - If 38% VSR cannot be achieved for aerobically digested biosolids, VAR can be demonstrated by further digesting a portion of the biosolids in a bench-scale unit for an additional 30 days at 20EC and achieving a further VSR of less than 15%.

Alt 4 - Aerobic Digestion (SOUR) - Specific Oxygen Uptake Rate of #1.5 mg oxygen/hour/g of TS at 20EC.

Alt 5 - Aerobic digestion for 14 days at > 40EC - Biosolids treated in an aerobic process for 14 days or longer at >40EC with an average temperature of >45EC.

Alt 6 - Alkaline Stabilization - The pH of biosolids must be raised to $12 for two hours and then at $11.5 for an additional 22 hours.

Alt 7 - Drying (%TSGT75) - The percent solids of biosolids that do not contain unstabilized solids generated in a primary wastewater treatment process must be $75%. Blending with other materials is not permitted to achieve the total solids percent.

Alt 8 - Drying (%TSGT90) - The percent solids of biosolids that contain unstabilized solids generated in a primary wastewater treatment process must be $90%. Blending with other materials is not permitted to achieve the total solids percent.

VAR Methods for Appliers of Biosolids

Alt 9 - Injection - (1) Biosolids are injected below the surface of the land. (2) No significant amount of the biosolids must be present on the land surface within one hour after the biosolids are injected. (3) When the biosolids that are injected are Class A with respect to pathogens, the biosolids must be injected below the land surface within eight hours after being discharged from the pathogen treatment process.

Alt 10 - Incorporation - Biosolids applied to land or placed on a surface disposal site must be incorporated into the soil within six hours after application or placement. When the biosolids that are incorporated into the soil are Class A with respect to pathogens, the biosolids must be applied to or placed on the land within eight hours after being discharged from the pathogen treatment process.

Alt 11 - Surface Disposal Daily Cover - Biosolids placed in a surface disposal site must be covered with soil or other material at the end of each operating day.

Alt 12 - Domestic Septage Treatment - The pH of domestic biosolids must be raised to 12 or higher by alkali addition and, without the addition of more alkali, must remain at 12 or higher for 30 minutes.

Table 2.7-1. List of Equivalent PSRP and PFRP Processes as of September 1989.

Excerpted from: *Environmental Regulations and Technology - Control of Pathogens in Municipal Wastewater Sludge*, USEPA Center for Environmental Research Information, Cincinnati, OH. September 1989, p. 27.

Processes Determined to Be Equivalent to PSRP or PFRP

Operator	Process Description	Status
Town of Telluride, Colorado	Combination oxidation ditch, aerated storage, and drying process. Biosolids are treated in an oxidation ditch for at least 26 days and then stored in an aerated holding tank for up to a week. Following dewatering to 18% solids, the biosolids are dried on a paved surface to a depth of 2 feet. The biosolids are turned over during drying. After drying to 30% solids, the biosolids are stockpiled prior to land application. Together, the drying and stockpiling steps take approximately 1 year. To ensure that PSRP requirements are met, the stockpiling period must include one full summer season.	PSRP
Comprehensive Materials Management, Inc., Houston, Texas	Use of cement kiln dust (instead of lime) to treat biosolids by raising biosolids pH to at least 12 after 2 hours of contact. Dewatered biosolids are mixed with cement kiln dust in an enclosed system and then hauled off for land application.	PSRP
N-Viro Energy Systems Ltd., Toledo, Ohio	Use of cement kiln dust and lime kiln dust (instead of lime) to treat biosolids by raising the pH. Sufficient lime or kiln dust is added to biosolids to produce a pH of 12 for at least 12 hours of contact.	National PSRP

Processes Determined to Be Equivalent to PSRP or PFRP

Operator	Process Description	Status
Public Works Department, Everett, Washington	Anaerobic digestion of lagooned biosolids. Suspended solids had accumulated in 30-acre aerated lagoon that had been used to aerate wastewater. The lengthy detention time in the lagoon (up to 15 years) resulted in a level of treatment exceeding that provided by conventional anaerobic digestion. The percentage of fresh or relatively unstabilized biosolids was very small compared to the rest of the accumulation (probably much less than 1% of the whole).	PSRP
Haikey Creek Wastewater Treatment Plant, Tulsa, Oklahoma	Oxidation ditch treatment plus storage. Biosolids are processed in aeration basins followed by storage in aerated biosolids holding tanks. The total biosolids aeration time is greater than the aerobic digestion operating conditions specified in the Federal regulations of 40 days at 20EC (68EF) to 60 days at 15EC (59EF). The oxidation ditch biosolids are then stored in batches for at least 45 days in an unaerated condition or 30 days under aerated conditions.	PSRP
Ned K. Burleson & Associates, Inc., Fort Worth, Texas	Aerobic digestion for 20 days at 30EC (86EF) or 15 days at 35EC (95EF)	PSRP
Scarborough Sanitary District, Scarborough, Maine	Static pile aerated Acomposting@ operation that uses fly ash from a paper company as a bulking agent. The process creates pile temperatures of 60E to 70EC (140E to 158EF) within 24 hours and maintains these temperatures for up to 14 days. The material is stockpiled after 7 to 14 days of Acomposting@ and then marketed.	PFRP
Mount Holly Sewage Authority, Mount Holly, New Jersey	Zimpro 50-gpm low-pressure wet air oxidation process. The process involves heating raw primary biosolids to 177E to 204EC (350E to 400EF) in a reaction vessel under pressures of 250 to 400 psig for 15 to 30 minutes. Small volumes of air are introduced into the process to oxidize the organic solids.	PFRP
N-Viro Energy Systems Ltd., Toledo, Ohio	Advanced alkaline stabilization with subsequent accelerating drying. $ Alternative 1: Fine alkaline materials (cement kiln dust, lime kiln dust, quicklime fines, pulverized lime, or hydrated lime) are uniformly mixed by mechanical or aeration mixing into liquid or dewatered biosolids to raise the pH to greater than 12 for 7 days. If the resulting biosolids are liquid, they are dewatered. The stabilized biosolids cake is then air dried (while pH remains above 12 for at least 7 days) for at least 30 days and until the cake is at least 65% solids. A solids concentration of at least 60% is achieved before the pH drops below 12. The mean temperature of the air surrounding the pile is above 5EC (41EF) for the first 7 days. $ Alternative 2: Fine alkaline materials (cement kiln dust, lime kiln dust, quicklime fines, pulverized lime, or hydrated lime) are uniformly mixed by mechanical or aeration mixing into liquid or dewatered biosolids to raise the pH to greater than 12 for at least 72 hours. If the resulting biosolids are liquid, they are dewatered. The biosolids cake is then heated, while the pH exceeds 12, using exothermic reactions or other thermal processes	National PFRP

PROCESSES DETERMINED TO BE EQUIVALENT TO PSRP OR PFRP

OPERATOR	PROCESS DESCRIPTION	STATUS
	TO ACHIEVE TEMPERATURES OF AT LEAST 52EC (126EF) THROUGHOUT THE BIOSOLIDS FOR AT LEAST 12 HOURS. THE STABILIZED BIOSOLIDS ARE THEN AIR DRIED (WHILE PH REMAINS ABOVE 12 FOR AT LEAST 3 DAYS) TO AT LEAST 50% SOLIDS.	
MIAMI-DADE WATER AND SEWER AUTHORITY, MIAMI, FLORIDA	ANAEROBIC DIGESTION FOLLOWED BY SOLAR DRYING. BIOSOLIDS ARE PROCESSED BY ANAEROBIC DIGESTION IN TWO WELL-MIXED DIGESTERS OPERATING IN SERIES IN A TEMPERATURE RANGE OF 35E TO 37EC (94E TO 99EF). TOTAL RESIDENCE TIME IS 30 DAYS. THE BIOSOLIDS ARE THEN CENTRIFUGED TO PRODUCE A CAKE OF BETWEEN 15 TO 25% SOLIDS. THE BIOSOLIDS CAKE IS DRIED FOR 30 DAYS ON A PAVED BED AT A DEPTH OF NO MORE THAN 46 CM (18 INCHES). WITHIN 8 DAYS OF THE START OF DRYING, THE BIOSOLIDS ARE TURNED OVER AT LEAST ONCE EVERY OTHER DAY UNTIL THE BIOSOLIDS REACH A SOLIDS CONTENT OF GREATER THAN 70%. THE PFRP APPROVAL WAS CONDITIONAL ON THE MICROBIOLOGICAL QUALITY OF THE PRODUCT.	CONDITIONAL PFRP

REQUIREMENTS FOR THE LONG-TERM TREATMENT PFRP EQUIVALENCY OPTION

(A.K.A. THE ATWO SUMMER METHOD@)

The requirements listed below are what EPA Region VIII requires in order for a facility to use the long-term treatment PFRP equivalency option. These include recommendations the Pathogen Equivalency Committee (PEC) made in order to approve the use of this option. In the future when more information on this process has been collected, some of the monitoring may be reduced (*e.g.*, helminth ova testing). Until that time, these are the requirements:

$ The biosolids must meet the Class B requirements <u>before</u> they are placed in the storage piles for long-term treatment and must be stored over two summers (a minimum of 15 months).

$ The biosolids must have a total solids content of at least 14%, but no more than 35% when the piles are formed.

$ The piles are to be formed into windrows at least 3.5 feet, but no more than 6.0 feet in height.

$ During the first summer the total solids in the pile are not to exceed 60%.

$ The average temperature of the pile must exceed 20EC for 12 months of the storage period (not necessarily consecutive months).

$ The pile shall be turned at least three times (at evenly spaced intervals) during each summer period.

$ The finished biosolids must not contain more than one viable helminth ova per four grams of total solids (dry weight basis) and must meet the fecal coliform limits (<1000 MPN/gram of total solids) or the *Salmonella* limits (<3 MPN/4 grams of total solids).

$ The biosolids must be monitored for helminth ova once for each batch.

$ At each turning of the pile, the biosolids shall be monitored for volatile solids and total solids. The average pile temperature must be monitored monthly.

$ The biosolids are not required to be monitored for enteric viruses if all other conditions listed for long-term treatment are followed.

SECTION 2.8 - PRACTICAL GUIDE TO SMALL SCALE COMPOSTING

INTRODUCTION

The purpose of this fact sheet is to provide basic information about composting municipal biosolids at small wastewater treatment plants. Composting is a biological process for turning a waste into a useful, stable material with nutrient and soil conditioning benefits. Since the 1970's, composting has steadily gained the attention of municipal sewage treatment plants as a cost-effective biosolids management option. There are currently 201 operating compost facilities with 117 more in planning or design (Goldstein, 1994). Many of these facilities are operated by small wastewater treatment plant operators. In particular, many small wastewater treatment plants have adopted composting because of the relatively low capital investment required and the benefits realized due to the marketability of the product.

Composting biosolids is one way to meet 40 CFR Part 503 pathogen (and vector attraction) reduction requirements. Composting biosolids can meet either a "Process to Significantly Reduce Pathogens" (PSRP/Class B) or a "Process to Further Reduce Pathogens" (PFRP/Class A) standard, depending upon the operating conditions maintained at the facility. The 40 CFR Part 503 regulations would require composted biosolids applied to the land to meet specific pollutant limits, site restrictions, management practices, and pathogen and vector attraction reduction processes, depending upon whether they: 1) are applied to agricultural land, forest, a public contact site, or a reclamation site; 2) are biosolids that are sold or given away in a bag or other container; or 3) are applied to a lawn or home garden.

THE BIOSOLIDS COMPOSTING PROCESS

The addition of a bulking agent to biosolids provides optimum conditions for the composting process, which usually lasts 3 to 4 weeks. A bulking agent acts as a source of carbon for the biological process, increases porosity, and reduces the moisture level. The composting process has several phases, including the active phase, the curing phase, and the drying phase.

Active phase. During the active or stabilization phase, the biosolids/bulking agent mix is aerated and biosolids are decomposed due to accelerated biological activity. The biological process involved in composting can raise the temperature up to 60EC. At these high temperatures, the majority of disease-causing bacteria (pathogens) are destroyed. The first phase typically lasts at least 21 days, but can last up to 30 days or more. Aeration is accomplished in one of two ways: 1) by mechanically turning the mixture so that the biosolids are exposed to oxygen in the air; or 2) by using blowers to either force or pull air through the mixture.

Curing phase. After the active phase, the resulting material is cured for approximately 30 days. At this time, additional decomposition, stabilization, pathogen destruction, and degassing takes place. Composting is considered complete when the temperature of the compost returns to ambient levels. Depending upon the extent of biodegradation during the active phase and the ultimate application of the finished product, the curing phase may not be carried out as a separate process.

Drying Phase. After curing, some operations add another step called the drying phase which can vary from days to months. This stage is necessary if the material is to be screened to either recover the unused bulking agent for recycling or for a more finished product. If the product is to be marketable, the final compost should be 50% to 60% solids.

There are two main process configurations for the composting process:

Unconfined composting. This process is conducted in long piles (windrows) or in static piles. Operations using unconfined composting methods may provide oxygen to the compost by turning the piles by hand or machine or by using air blowers which may be operated in either a positive (blowing) or negative (suction) mode. For windrows without blower aeration, it is typical to turn the windrow two or three times a week, using a front end loader. Properly operating aerated static piles do not require turning.

Confined (in-vessel) composting. This process is carried out within an enclosed container, which minimizes odors and process time by providing better control over the process variables. Although in-vessel composting has been effective for small operations, typically these operations are proprietary and therefore will not be described any further in this fact sheet.

DESIGN CONSIDERATIONS

The key process variables for successful composting are the moisture content and carbon to nitrogen (C:N) ratio of the biosolids/bulking agent mixture, and temperature and aeration of the compost pile. Other process parameters such as volatile solids content, pH, mixing and the materials used in the compost also affect the process.

Biosolids/Bulking Agent Mixture Moisture Content. Moisture control is an important factor for effective composting. Water content must be controlled for effective stabilization, pathogen inactivation, odor control and finished compost quality (Benedict, 1988). The optimum moisture content of the mix is between 40% and 60%. At less than 40% water, the material is too fluid, has reduced porosity and has the potential for producing septic conditions and odors; above 60% solids, the lack of moisture may slow down the rate of decomposition. Since typical dewatered biosolids are often in the range of 15% to 20% solids for vacuum filtered biosolids and 20% to 35% solids for belt press or filter pressed biosolids, the addition of drier materials (bulking agents) is usually essential.

Biosolids/Bulking Agent Mixture Carbon to Nitrogen Ratio. Microorganisms need carbon for growth and nitrogen for protein synthesis. For efficient composting, the carbon to nitrogen (C:N) ratio of the biosolids/bulking agent mixture should be in the range of 25:1 to 35:1. Table 2.8-1 shows the C:N ratios of various compostable materials as well as their percent nitrogen.

Temperature levels. Optimum temperature levels for the composting process are between 45E and 55EC. Temperatures should not be allowed to exceed 65EC (149EF) because the bacteria that are the most effective for organic destruction will be severely inhibited. Temperatures reached in the composting operation are critical in determining whether the final compost is Class A or Class B with respect to pathogens as defined by 40 CFR Part 503, Subpart D. These classifications are based on the following operational standards.

For class A biosolids, the composted biosolids must meet the pathogen density requirements in 40 CFR Part 503 and meet the PFRP requirements, including the following temperature/time requirements:

Table 2.8-1

Approximate Nitrogen Content and C:N Ratios of Some Compostable Material, Dry Basis

Material	**N(%)**	**C:N**
Poultry manure	6.3	--
Mixed slaughterhouse waste	7-10	2
Activated biosolids	5.0-6.0	6
Digested biosolids	1.9	16
Sheep manure	3.75	--
Pig manure	3.75	--
Horse manure	2.3	--
Farmyard manure (avg.)	2.15	14
Seaweed	1.9	19
Weeds	2.0	19
Cow manure	1.7	--
Potato tops	1.5	25
Combined refuse (avg.)	0.5-1.4	30-80
Food wastes	2.0-3.0	15
Fruit wastes	1.5	35
Oat straw	1.05	48
Wheat straw	0.3	128
Paper	0.2	170

Fresh sawdust	0.11	511
Newspaper	nil	--
Wood	0.07	700

From Gotaas, H.G., 1956, *Composting. Sanitary Disposal and Reclamation of Organic Wastes*, WHO Monograph Series 31, World Health Organization, Geneva.

- Aerated static piles and in-vessel systems must be maintained at a minimum operating temperature of 55EC (131EF) for at least 3 days; and

- Windrow piles must be maintained at a minimum operating temperature of 55EC (131EF) for 15 days or longer. The piles must be turned three times during this period.

For class B biosolids, aerated static pile, conventional windrow and in-vessel composting methods must meet the PSRP requirements, including the following temperature/time requirements:

- The compost pile must be maintained at a minimum of 40EC for at least five days; and

- During the five-day period, the temperature must rise above 55EC for at least four hours to ensure pathogen destruction. This is usually done near the end of the active composting phase in order to prevent inactivating the organic destroying bacteria.

To meet 40 CFR Part 503 vector attraction reduction requirements using the "aerobic process" alternative, composting operations must ensure that the process lasts for 14 days or longer at a temperature greater than 40EC. In addition, the average temperature must be higher than 45EC.

The surface area to volume ratio has an effect on the temperature of the pile. Assuming other factors are constant (e.g., moisture, composition, aeration), larger piles (with their lower surface area to volume ratio), retain more heat than smaller piles. Ambient temperatures have a significant impact on composting operations (Benedict, 1988).

Oxygen levels. For optimum aerobic biological activity, air within the pile should have oxygen levels of between 5% and 15%. Lower levels of oxygen will create odors and reduce the efficiency of the composting. Excessive aeration will cool the pile, slow the composting process, and will not provide the desired pathogen and vector attraction reduction.

Conventional windrows obtain necessary oxygen through the natural draft and ventilation induced from the hot, moist air produced during active composting and from the periodic windrow turning. Where blowers are used for aeration, it is typical to provide at least one blower per pile.

Biosolids/Bulking Agent Mixture Volatile Solids Content. The volatile solids content of the biosolids/bulking agent mix should be greater than 50% for successful composting (EPA, 1985). This parameter is indicative of the energy available for biological activity.

Biosolids/Bulking Agent Mixture pH. The pH of the biosolids/bulking agent mix should be in the range of 6 to 9 for efficient composting (EPA, 1985). Higher pH mixtures may result if lime stabilized biosolids are used. They can be composted; however, it may take longer for the composting process to achieve the temperatures needed to reduce pathogens.

Biosolids and Bulking Agent Mixing. Uniform mixing is necessary in order to assure that moisture concentration is constant through the pile and that air can flow throughout. A mixing time of 40-45 minutes is typical.

Type of Biosolids. The type of biosolids used may have an effect on the composting process. Composting can be accomplished with unstabilized biosolids, as well as anaerobically and aerobically digested biosolids. Raw biosolids have a greater potential to cause odors because they have more energy available and will, therefore, degrade more readily. This may cause the compost pile to achieve higher temperatures faster unless sufficient oxygen is provided and may also cause odors (EPA, 1985).

Material for Bulking Agents. Materials such as wood chips, sawdust and recycled compost are usually added as "bulking agents" or "amendments" to the compost mixture to provide an additional source of carbon and to control the moisture content of the mixture. Other common bulking agents used by facilities around the country include wood waste, leaves, brush, manure, grass, straw, and paper (Goldstein, 1994). Because of their cost, wood chips are often screened out from the matured compost, for re-use. Although sawdust is frequently used for in-vessel composting, coarser materials such as wood chips, wood shavings, and ground-up wood are often preferred because they permit better air penetration and are easier to remove. Recycled compost is often used as a bulking agent in windrows, especially if bulking agents must be purchased. However, its use is limited because the porosity decreases as the recycle ages (EPA, 1989).

The amount of biosolids and bulking agent which must be combined to make a successful compost is based on a mass balance process considering the moisture contents, C:N ratio, and volatile solids content.

COMPOSTING OPERATION AND SITING CONSIDERATIONS

Composting Performance

A range from 0.4 to 1 cubic yard of finished compost was generated per wet ton of biosolids in one compost plant survey. This is equivalent to about 0.7 to 2.0 dry tons of compost per dry ton of biosolids. The larger volumes are due to the incorporation of wood chip fines or other amendment materials which are not removed during screening. Finished static pile compost was found to have a total solids contents from about 50% to 69% and bulk densities of 900 to 1,500 pounds per cubic yard. Finished windrow compost had solids contents of up to 60% (Benedict, 1988).

Compost Pile Size

IN GENERAL, ASSUMING ADEQUATE AERATION, THE LARGER THE PILE THE BETTER. A LARGER PILE HAS LESS SURFACE AREA PER CUBIC YARD OF CONTENTS AND THEREFORE RETAINS MORE OF THE HEAT THAT IS GENERATED AND IS LESS INFLUENCED BY AMBIENT CONDITIONS. IN ADDITION, LESS COVER AND BASE MATERIAL (RECYCLED COMPOST, WOOD CHIPS, ETC.) IS NEEDED AS WELL AS THE OVERALL LAND REQUIREMENTS FOR THE COMPOST OPERATION.

A typical aerated static pile for a large operation would be triangularly shaped in cross section about 3 meters(m) high by 4.5 to 7.5 m wide (15 to 25 feet) at the base by 12 to 15 m long (39 to 50 feet) (Haug, 1980). One survey study indicates that extended aerated static pile (where piles are formed on the side of older piles) heights were typically 12 to 13 feet high. Minimum depths of base and cover materials (recycled compost, wood chips etc.) were 12 and 18 inches, respectively (Benedict, 1988).

In windrow composting, the compost mix is stacked in long parallel rows. In cross section, windrows may range from rectangular to trapezoidal to triangular, depending upon the material and the turning equipment. A typical trapezoidal windrow might be 1.2 m (4 feet) high by 4.0 m (13 feet) at its base and 1.0 m (3 feet) across the top (Haug, 1980).

Land Requirements

Unit operation area requirements in acres per wet ton per day (ac/wtpd) is site- and process-specific. Requirements depend on variables such as daily biosolids loadings, storage requirements, drying techniques, composting method and runoff control. In one study, a range of 0.08 to 0.14 ac/wtpd was found (Benedict, 1988). Typically, operations are carried out on paved surfaces which permit collection and treatment of runoff. Enclosing or covering key operating areas such as areas where static piles are mixed are common, especially in areas with high annual precipitation.

Equipment Requirements

Unconfined composting in static piles and windrows requires materials moving and mixing equipment. Front end loaders are often used for rough mixing, pile construction, pile teardown activities and materials storage and transfer operations. Specialized equipment such as mobile composters are used for fine mixing and windrow turning. Other equipment may include dump trucks, drum screens and aeration blower assemblies (Benedict, 1988).

Manpower Requirements

Manpower requirements are highly variable and site specific. Static pile operations tend to be more labor intensive than conventional windrow operations.

Odor Control

Odor is often the major problem and impediment to a successful composting operation. Careful planning should be done to assure that operations are conducted in an area and in a manner that will not produce nuisance complaints. A good public relations effort can help to minimize these problems. However, a program to minimize odors is essential.

In general, using partially stabilized (e.g., anaerobically digested) biosolids will decrease odors. Additionally, as listed below, certain design and operational features can help to minimize odor generation (Benedict, 1988):

$ TRUCKS HAULING DEWATERED BIOSOLIDS SHOULD BE COVERED AND FREQUENTLY CLEANED;

$ BEFORE COMPOSTING, PILES OF BIOSOLIDS SHOULD NOT BE ALLOWED TO SIT FOR PROLONGED PERIODS OF TIME. THE COMBINATION OF HOT WEATHER AND AGING RAW BIOSOLIDS ASSURE ODOR GENERATION;

$ AN INITIAL SOLIDS CONTENT OF 40% OR MORE IS CRITICAL FOR ODOR CONTROL. A UNIFORM, THOROUGH MIX IS NEEDED TO AVOID CLUMPS AND THE GENERATION OF ODORS DUE TO ANAEROBIC FERMENTATION;

$ STATIC PILES SHOULD BE COVERED DAILY WITH A LAYER OF FINISHED COMPOST OR BULKING AGENT. ENCLOSING THE ENTIRE OPERATION AND PROVIDING EXHAUST GAS SCRUBBING CAN ALSO BE EFFECTIVE IN SOME SITUATIONS;

$ LIMITING THE QUANTITY OF BIOSOLIDS TO BE COMPOSTED DAILY CAN HELP REDUCE ODORS;

$ WHEN AIR IS DRAWN INTO THE AN AERATED STATIC PILE (NEGATIVE PRESSURE) A SEPARATE EXHAUST SCRUBBER SYSTEM SHOULD BE USED PRIOR TO ATMOSPHERIC DISCHARGE. THIS MAY BE A FINISHED COMPOST PILE OR A MORE COMPLEX SYSTEM (E.G., BIOFILTER, DISCHARGING INTO THE WASTEWATER TREATMENT PLANT);

$ TEARDOWN OF PILES CAN RELEASE ODORS. IT IS RECOMMENDED THAT HIGH RATE AERATION FOR 24 TO 48 HOURS BEFORE PILE TEARDOWN BE USED IN ORDER TO LOWER THE PILE TEMPERATURE AND TO CONTROL ODOR RELEASES. ALSO, RESTRICTING TEARDOWNS TO TIMES WHEN AIR INVERSIONS CAN OCCUR OR WINDS ARE HIGH CAN HELP;

$ PROPER SITE DRAINAGE IS NEEDED TO PREVENT PONDING AND ODOR GENERATION. LEACHATE, CONDENSATE AND RUNOFF SHOULD BE COLLECTED AND DISPOSED OF, AND;

$ EFFECTIVE HOUSEKEEPING PROCEDURES SUCH AS WASHING EQUIPMENT, FLUSHING AND SWEEPING WORKING AREAS ARE IMPORTANT.

OTHER METHODS WHICH HAVE BEEN USED TO CONTROL ODORS FROM IN-VESSEL FACILITIES INCLUDE: 1) DILUTING ODORS WITH LARGE VOLUMES OF AIR; 2) BUBBLING THE AIR THROUGH THE MIXED LIQUOR IN THE TREATMENT PLANT; 3) PASSING THE AIR THROUGH COMPOST "EARTH" BIOFILTERS; AND 4) TREATING THE AIR CHEMICALLY THROUGH OZONE OXIDATION OR SCRUBBERS. FREQUENTLY, HOWEVER, THESE TECHNIQUES HAVE HAD LIMITED SUCCESS (EPA, 1989).

DUST CONTROL

DUST GENERATION AND RELEASE OF BACTERIA AND FUNGI, SUCH AS *A. FUMIGATUS AEROSPORA*, IS A POTENTIAL PROBLEM AT COMPOST FACILITIES AND CAN BE MINIMIZED BY AVOIDING OVERDRYING, MINIMIZING PILE TURNING AND MOVING DURING WINDY PERIODS, COVERING PILES WITH RECYCLED MATERIALS, AND ENCLOSING FACILITIES.

TROUBLE-SHOOTING COMPOSTING OPERATIONS

Because composting operations must be designed based on numerous site-specific conditions and parameters, guidance on the proper operation of a facility is difficult to provide in general terms. Therefore, a list of potential problems, causes and possible solutions has been provided in Table 2.17-2 for the small wastewater treatment operator to consider.

A TYPICAL BIOSOLIDS COMPOST OPERATION

An example of a typical, hypothetical biosolids composting operation is presented below in order to give a general understanding of the steps involved in composting. The process described is for an aerated static pile.

On a paved surface, a layer of dewatered biosolids is dumped onto a 6- to 12-inch layer of wood chips. The wood chips, used as a bulking agent, are mixed at a ratio of approximately 2.5-4.5 cubic yards of chips to one ton of wet biosolids. Finished compost is often also added. These additives reduce the overall moisture content and provide structure to the pile, enhancing air flow. The total mix should have a solids content of approximately 50%. The biosolids and wood chips are then mixed by a small front end loader to produce a uniform mixture with no large biosolids balls. A rototiller might also be used to complete the mixing. A pile is then formed which may be 5 to 13 feet high. The pile is placed over a perforated piping system in a bed of wood chips and the piping system attached to a suction blower. This blower discharges through a recycled compost pile for odor control. The main compost pile is covered with a layer of recycled compost. Ideally, the pile area is covered or enclosed to protect it from the elements and to help control odors.

During a 21-day period, the compost goes through the active phase of composting. During the first week, 3,500 to 4,000 cubic feet per hour (cfh) of air per dry ton of biosolids is used to promote material decomposition and odor control. During the next two weeks, aeration is controlled to maintain the temperature between 40E and 60EC, including a minimum of 3 days above 55E (as required by 40 CFR Part 503); aeration is increased to 6,000 cfh per dry ton for drying and odor control. If the temperature objectives are not met, the biosolids is recycled into new piles. Temperature and oxygen are monitored daily with portable meters at several points in the pile.

At the end of this period, if the material is not sufficiently dry, it is placed on a slab 15 to 18 inches thick, rototilled and allowed to let stand until a 50% solids level is obtained. About 1,500 square feet per wet ton per day would be needed. For approximately 30 days, the compost is cured for additional destruction of pathogens and additional drying. A positive blower for aeration may be used.

Finished compost usually requires mechanical screening to the 1/4" to 3/8" range, which will typically recover 65% to 85% of the wood chips. The recycled chips are stored for reuse. The finished compost is stored in covered areas for future distribution and for use as a compost amendment.

Table 2.8-2. Potential Problems, Causes, and Possible Solutions for Biosolids Composting Operations.

Problem	Potential Cause		Possible Solution
1. Slow or low temperature rise	1.	Low oxygen supply	
	1.1	Low oxygen flow	
	1.1.1	Plugged pipe	Clean out perforations and pipe
	1.1.2	Low blower capacity	Check air flow; increase flow; increase blower size
	1.1.3	Low pile porosity	Add more bulking agent; check dryness
	1.2	Incorrect C:N ratio	
	1.2.1	Low carbon supply	Add more or change bulking agents
	1.2.1	Low nitrogen supply	Check percent nitrogen of biosolids; increase biosolids percent
	1.3	Incorrect solids content	
	1.3.1	Too dry	Check if initial biosolids is more than 50% solids; water pile
	1.3.2	Too wet	Check if mixture is less than 45%; increase biosolids dryness; add more dry bulking agent; change bulking agent; increase bulking agent size
	1.4	Cold ambient conditions	Form larger piles; cover with more recycled compost; shield or enclose area
2. Odor Creation	2.1	Anaerobic conditions in pile	
	2.1.1	Low porosity	Add more bulking agent; use drier biosolids or bulking agent; mix better
	2.1.2	Limited oxygen flow	Increase aeration
	2.1.3	Poorly mixed biosolids and bulking agent	Mix for longer time; use other equipment (e.g., rototiller)
	2.2	Poor runoff drainage	Correct drainage; recycle to plant
	2.3	Poor housekeeping	Wash down all equipment, trucks, etc.
	2.4	Poor weather conditions for turning, breakdown and moving piles	Avoid activity during windy periods or when temperature inversions can occur
	2.5	Type of biosolids	Use digested instead of raw biosolids; lime treat raw biosolids
	2.6	Biosolids too wet	Add more bulking agent to increase solids above 40%
	2.7	Accumulation of biosolids	Limit time biosolids are allowed to sit at site
	2.8	Poor odor control	Use odor control system such as biofilter, scrubbing system or masking agents
3. Dust	3.1	Biosolids too dry	Limit biosolids solids content less than 65-70% solids; water if needed

Table 2.8-2. Potential Problems, Causes, and Possible Solutions for Biosolids Composting Operations.

Problem	Potential Cause	Possible Solution
Production		
	3.2 Compost turning, teardown	Use forced aeration instead of turning; limit activities to minimum and during low wind conditions; spray while turning; enclose mixing area especially if recycled compost is used
	3.3 Equipment activity on unpaved areas	Pave areas
	3.4 Poor housekeeping	Wash down roads, equipment

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WEF RESIDUAL MANAGEMENT COMMITTEE, ABIOSOLIDS AND THE 503 STANDARD,@ *WATER ENVIRONMENT & TECHNOLOGY*, MAY 1993.

SAMPLE HANDOUT TO COMPOST RECIPIENTS

THE FOLLOWING DOCUMENT IS AN EXAMPLE OF AN INFORMATION SHEET THAT COULD BE GIVEN TO PEOPLE WHO HAVE EITHER PURCHASED OR RECEIVED FREE COMPOST. THE INFORMATION COULD BE TAILORED TO MEET YOUR SPECIFIC SITUATION. THE DOCUMENT CAN BE DOWNLOADED AT HTTP://CRU32.CAHE.WSU.EDU/STEWARDSHIP/BIOSOLID/BIOSOLID.HTM (*BIOSOLIDS: A RECYCLED ORGANIC FERTILIZER* BY WASHINGTON STATE UNIVERSITY COOPERATIVE EXTENSION); USED WITH PERMISSION OF WASHINGTON STATE UNIVERSITY EXTENSION.

BIOSOLIDS

A RECYCLED ORGANIC FERTILIZER

Biosolids are the treated solid material left over from the wastewater treatment process. Biosolids, also called sewage sludge, contains water, sand, nutrients used as a fertilizer, a small number of microorganisms and trace amounts of metals and chemicals.

Much of the biosolids is recycled on land in agriculture, forestry, as a soil improver and in composting projects. Biosolids are a valuable source of fertilizer nutrients and are used in a wide variety of crops, including wheat, barley, hops, rangeland or are composted and used in yards and gardens. Biosolids contain significant amounts of all nutrients required by plants, including nitrogen, phosphorus, potassium, and micronutrients. Because biosolids vary by source and treatment process, different biosolids will contain different amounts of these nutrients.

Biosolids are soil conditioners and in a short time after being added to the soil, will resemble a rich, organic topsoil. The organic matter increases water retention and retains nutrients in the soil, similar to the effects of peat moss, and helps plants withstand drought. In addition, organic matter improves soil tilth, making the soil easier to work and permits easier root penetration. Adding biosolids to the soil can both improve water retention and accelerate plant establishment, potentially reducing storm-water runoff and erosion.

The Environmental Protection Agency has defined two classes of biosolids as they relate to pathogens, organisms that are capable of causing diseases in humans. A designation of "Class A" means that all pathogens have been destroyed in the treatment process. Class A can be achieved through a digestion which heats biosolids to 140 °F, through composting the biosolids, or with heat drying to produce a pellet or granular product. Class B means that there has been a significant reduction of pathogens in the biosolids but have not been eliminated. Both Class A and Class B materials are safe for land application, however, additional management practices are required of Class B products. Class A products may be used in any setting, including home lawn and gardens. Examples of Class A products include Tagro from the City of Tacoma, Washington; GroCo from King County, Washington; and Milorganite from Milwaukee, Wisconsin.

Biosolids can be composted with several different materials. The most common in Washington is sawdust or wood chips. Currently, yard waste has become a common bulking agent in composting biosolids. Composting, the biological decomposition of organic matter, produces a stable, drier biosolids product with about half water and half solids. During decomposition, some materials in the biosolids are converted to gas, water and heat. This dries the compost, while the heat generated increases the efficiency of the composting process and kill pathogens.

More information about this topic is available through your <u>local Cooperative Extension Office</u>

Source: James A. Kropf, Extension Faculty, Horticulture, Small Farms and Farm Marketing. (1998)

Using biosolids in your yard: Health and safety questions and answers

<u>Biosolids: A recycled organic fertilizer</u>

Using biosolids in your yard: Health and safety questions and answers

<u>Stewardship gardening links outside WSU</u>

Are biosolids available for private yards or gardens, and if so, is there any problem using biosolids on vegetables or around children?

Some municipalities give biosolids away or sell it to the general public for landscaping or gardening purposes. Biosolids used around home must be treated by a process to further reduce pathogens such as composting, heat treatment or thermophilic digestion. In some places the biosolids are composted with sawdust or other bulking agents and sold as a topsoil or soil amendment. Biosolids compost makes an excellent mulch, soil amendment and substitute for manure composts, peat moss and other elements used in soil mixes. Class A biosolids may be used for landscaping and gardening purposes, however, when growing food crops with biosolids it is recommended that the user maintain the soil pH at or above 6.0. Keeping the soil pH at this level immobilizes the trace metals in the soil, minimizing absorption by plants.

Can land application of biosolids transmit trace metals and thereby endanger human health?

Of the various metals found in biosolids, cadmium and lead are of the greatest concern to human health. The greatest accumulation of cadmium in the food chain is in the leaves of certain plants and in the livers and

KIDNEYS OF ANIMALS THAT LIVE IN OR NEAR THE SOIL. RESEARCH HAS SHOWN THAT LEAD DOES NOT ACCUMULATE SIGNIFICANTLY IN PLANTS AND INTO THE ORGANS OF WILDLIFE SUCH AS DEER. IT WAS ALSO FOUND THAT LEAD LEVELS WERE NOT ELEVATED IN BLACKBERRIES GROWN IN THE TREATED FOREST. CADMIUM DOES ACCUMULATE IN PLANTS, PARTICULARLY IN LEAFY VEGETABLES AND ROOT CROPS. EPA RISK ASSESSMENT FOR VEGETABLES GROWN IN BIOSOLIDS-AMENDED SOILS SHOWS NO SIGNIFICANT HEALTH EFFECTS FROM EATING THESE VEGETABLES WHEN THE TRACE METALS IN THE BIOSOLIDS HAVE BEEN APPLIED AT REGULATED RATES.

COULD A PERSON INHALE AIRBORNE BACTERIA OR VIRUSES WHEN BIOSOLIDS ARE HANDLED OR APPLIED?

GARDENERS MUST ALWAYS USE COMMON SENSE WHEN HANDLING ANY CHEMICAL, FERTILIZER, MANURE, OR EVEN GARDEN SOIL. RESEARCH HAS SHOWN THAT CLASS A BIOSOLIDS CONTAIN NO PATHOGENS.

BACK TO BIOSOLIDS: A RECYCLED ORGANIC FERTILIZER. MORE INFORMATION ABOUT THIS TOPIC IS AVAILABLE THROUGH YOUR LOCAL COOPERATIVE EXTENSION OFFICE.

SOURCE: JAMES A. KROPF, EXTENSION FACULTY, HORTICULTURE, SMALL FARMS AND FARM MARKETING. (1998)

SECTION 2.9 C CONSERVATION TILLAGE AND WIND EROSION TECHNIQUES

THE FOLLOWING DOCUMENT PROVIDES EXAMPLES OF METHODS TO CONTROL SOIL AND WATER EROSION THROUGH THE USE OF STRUCTURAL CONTROLS, CULTURAL PRACTICES, AND MANAGEMENT PRACTICES AT BIOSOLIDS LAND APPLICATION SITES.

"RECOMMENDED MANAGEMENT PRACTICES FOR CONTROL OF SOIL EROSION AND SURFACE RUNOFF AT BIOSOLIDS APPLICATION SITES"

COLORADO DEPARTMENT
OF PUBLIC HEALTH
AND ENVIRONMENT

THIS DOCUMENT WAS PREPARED BY

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This document was produced by the Colorado Department Public Health and Environment, Biosolids Stakeholders Committee consisting of Robert Brobst of EPA, Charles Caudill of Littleton Englewood Wastewater Treatment Plant, Steve Frank of Metro Wastewater Reclamation District, Paul Grundelmann of Colorado Wastewater Utility Council, Paul Heppler of City of Boulder Wastewater Treatment Plant, Ron Jepson of Colorado State University Cooperative Extension, Adams County, Becky Patterson of Metro Wastewater Reclamation District, John Price of Deertrail Soil Conservation District, Brad Rock of Colorado Farm Bureau, Mike Scharp of Parker Ag Services, Lori Tucker of CDPH&E, and Pam Whelden of Colorado Association of Soil Conservation Districts.

This document offers examples of how to control soil and water erosion through the use of structural controls, cultural practices and management practices at biosolids land application sites. This document is intended to communicate information concerning erosion control practices and related issues to wastewater treatment facility staff, consultants, and biosolids management contractors. This document is not intended to be and will not be utilized as a basis to support mandated site management requirements but rather as a technology transfer device. Other alternatives may exist or may be developed.

For additional information on nutrient management and/or other agricultural practices contact:

Colorado Department of Public Health and Environment, Biosolids Program - 303/6923613, or @ www.cdphe.state.co.us/wq/wqhom.html

U.S. EPA Region VIll 303/312-6129, or @ www.epa.gov/owm/bio.html

Colorado Association of Soil Conservation Districts 303/232-6242 or @ www.nrcs

CSU Cooperative Extension Department of Soil and Crop Sciences - 970/491-6201 or @ www.colostate.edu/depts/coopext/PUBS/pubsmenu.html

Water Environment Federation - www.wef.org

The following sections, AWater Erosion" and AWind Erosion" are excerpted from ABest Management Practices for Wheat, A Guide to Profitable and Environmentally Sound Production" - A joint effort of the Cooperative Extension System and the National Association of Wheat Growers Foundation, Printed in the USA, 1994. "Runoff Water Quality" was produced by Rocky Mountain Water Environmental Assoc., Biosolids Committee.

RUNOFF WATER QUALITY

Why Should Runoff Water Quality Be a Problem?

Any fertilizer or soil conditioner, including biosolids or biosolids constituents, have the potential to be carried from applied areas during rainfall events. This runoff could cause contamination of surface waters and impact it uses.

What Does the Research Say?

Rainfall on agricultural sites that is hard enough or long enough will cause runoff. The question then becomes: Will the runoff be contaminated enough to cause pollution problems downstream of the application site? Runoff studies, to be of value, must be conducted in a manner so that one study can be compared with another. The standard test storm is represented by a 10 cm (4-Inch) per hour storm event. In practice, runoff is measured by 5 cm (2 inches) per 30 minutes using specific sprinkler heads. The following findings are from studies conducted on agricultural as well as grassland sites.

Effects on Surface Water from Dryland Agricultural Sites

In practice, the surface water pollution potential from applying biosolids is greatest for surface-applied biosolids applied on bare soil, followed by injected and/or incorporated biosolids. Agricultural practices are moving more and more toward more sustainable operations such as low-till/no-till in- an attempt to leave the soil's surface covered with organic matter. Studies (Mostaghimi et al, 1989) were completed utilizing a rainfall simulator to measure the effects of different tilling systems at different biosolids application rates.

The application method having the least potential for causing off-site contamination from surface water is surface-applied under a no-till farming program. The TKN (total nitrogen) in the runoff for conventional tillage/surface-applied biosolids was 1.5 times that for the no-till application. The NO,-N (nitrate-nitrogen) in the runoff for the conventional tillage/surface applied biosolids was 3.6 times that of the no-till systems.

Effects on Surface Water from Irrigated Agricultural Sites

The City of Fort Collins, Colorado, operates a resource recovery farm east of the city. To control nitrogen, the city has set up a nutrient management plan. The farm is a working farm raising corn as its primary crop. The farm was laser leveled in 1985 to aid in surface irrigation. Biosolids were applied to the farm at agronomic rates. In monitoring upstream irrigation water quality, as well as downstream irrigation water quality, the city found no significant change in all forms of nitrogen: $N0_3$-N, $N0_2$-N, NH_3-N, and TKN-N. (Houck et al, 1987)

Effects on Surface Water from Grasslands

Runoff and erosion generally increase with decreased vegetation and increased slope. Studies (Harris-Pierce et al, 1995, Aguilar et al, 1992) on and semiarid lands have shown that, of the constituents measured in runoff, all were less than the drinking water standards and below the recommended levels for livestock waters. Several papers found that, with each successive runoff event, the concentration of the constituents of concern was reduced by 55 percent to 80 percent (McLeod et al, 1984) with each successive storm event.

Significant reductions in both surface water runoff and erosion, even under simulated sever precipitation conditions on 10 percent slopes, were confirmed in US Forest Service/City of Albuquerque trials (Aguilar et al, 1992) at Sevilltea LTER Area. Runoff yields from the non-applied control plots increased progressively with increased precipitation and storm duration.

The biosolids-applied plots did not follow this pattern. The runoff from the treated plots remained 2 percent of the precipitation input. Several reasons have been suggested for the lack of runoff, one being the even distribution of the organic matter on the biosolids application sites. The other is that the biosolids, together with the high infiltration rates, reduced the site runoff.

RUNOFF WATER QUALITY

Effects on Soil Stability

Application of biosolids can reduce erosion through stabilizing the soil surface and promoting infiltration. Studies (Epstein et al 1975, Kelling et al 1977 and Kladivko et al 1979) have shown that this was accomplished through protection of the soil surface against rain drop impact and the associated erosion.

Management Practices That Minimize The Potential for Runoff

/ Surface application to no-till fields or fields with vegetative growth

/ Injection to bare fields or application followed by incorporation

/ Selection of fields with minimal slope

/ Use of vegetative buffer strips on the perimeter of applied areas as well as many other soil erosion control management practices.

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*Peer Reviewed Articles. "Peer review"means that the listed references have gone through a separate detailed scientific review by scientifically qualified peers before the article could be published. All of the references listed here have gone through that additional review process.

WATER EROSION

DEFINITIONS

Water erosion is the natural process of soil movement from higher areas to lower areas by the action of flowing water. During a storm event, precipitation may come so quickly that it cannot infiltrate, resulting in runoff. This creates the potential for water erosion. Activities such as soil cultivation and the destruction and the destruction of vegetative cover accelerate this process.

Water erosion can be separated into different forms based on how water is moving over the surface. At first, water will move a short distance as a thin film over the soil surface. Loss of soil in this thin film of water is known as sheet erosion. As the process continues, water begins to concentrate in small channels, or rills. Soil erosion during this process is termed rill erosion. The resulting sediment from sheet and rill erosion will be finer textured and will contain higher proportions of nutrients and other absorbed pollutants than that contained in the surface soil as a whole.

Water concentrated into rills will form larger and more persistent channels. These channels are known as ephemeral gullies and soil erosion from these channels is termed ephemeral gully erosion. Tillage generally removes these channels and they do not become permanent. Eventually runoff water reaches permanent, natural water courses, such as drainage ways and draws. These features typically run water only during peak runoff periods. Excessive soil erosion from these features causes gullies and this type of erosion is known as gully erosion. Gullies generally cannot be removed by tillage or crossed with equipment. Runoff water ultimately enters intermittent or perennial streams. Here, undercutting or other forms of erosion from the water's edge causes stream bank erosion. Gully and streambank erosion can remove larger soil - ' particle, and often contains a much lower proportion of nutrients and absorbed pollutants than sediment from sheet. and rill erosion. Erosion can also occur from the stream channel, such as channel scour. This form of erosion is often referred to as channel erosion.

All forms of erosion can be serious. Although gully or rill erosion are readily visible forms, sheet erosion may be responsible for the greater soil loss.

Factors Affecting Water Erosion

- Precipitation
  - amount
  - intensity
  - duration
  - seasonal distribution
  - form (rain, snow)
- Soil
  - organic matter content
  - structure
  - texture
  - infiltration rate
  - drainage
  - surface roughness
  - freezing
- Slope
  - steepness
  - length
  - shape
- Crop
  - residue
  - canopy
  - roots
- Management Practices
  - tillage
  - conservation structures
  - crop residue
  - stripcropping

PRINCIPLES OF WATER EROSION

WATER EROSION IS A COMBINATION OF THREE PROCESSES: (1) DETACHMENT, (2) TRANSPORT, AND (3) DEPOSITION. SEE THE GRAPHIC ON THE FOLLOWING PAGE. SOIL IS DETACHED BY RAINDROP IMPACT OR THE FORCE OF FLOWING WATER. ONCE DETACHED, SOIL PARTICLES ARE TRANSPORTED BY FLOWING WATER. DEPOSITION OCCURS WHEN WATER VELOCITY SLOWS AND SUSPENDED PARTICLES DROP OUT.

FACTORS AFFECTING WATER EROSION

WATER EROSION IS AFFECTED BY PRECIPITATION PATTERNS, SOIL PROPERTIES, VEGETATIVE COVER, AND CONSERVATION PRACTICES. FOR INSTANCE, THE FREQUENCY, INTENSITY, AND DURATION OF RAINFALL COMBINE WITH SLOPE LENGTH AND STEEPNESS TO DETERMINE THE VOLUME OF WATER AVAILABLE FOR EROSION, AND THE RATE AT WHICH IT LEAVES THE LAND.

WATER EROSION

PRINCIPLES		STRATEGIES FOR CONTROL
DETACHMENT DETACHMENT OCCURS WHEN WATER SPLASHES ONTO THE SOIL SURFACE AND DISLODGES SOIL PARTICLES FROM THEIR ORIGINAL LOCATION.	O	**MAINTAIN CROP RESIDUES OR VEGETATIVE COVER:** CROP RESIDUES OR VEGETATIVE COVER ON THE SOIL SURFACE INTERCEPT RAINDROPS, DISSIPATING THE ENERGY FROM THE FAILING RAINDROPS AND HELPING REDUCE THE DETACHMENT OF SOIL PARTICLES. **IMPROVE SOIL PROPERTIES**: SOIL MANAGEMENT TO PRESERVE ORGANIC MATTER, SOIL STRUCTURE, AND TILTH IMPROVES WATER INFILTRATION AND CLOD STABILITY AND THUS REDUCES DETACHMENT OF SOIL PARTICLES BY FAILING RAINDROPS OR SURFACE WATER FLOW. **SOIL ROUGHNESS:** A ROUGH SURFACE WILL BREAK THE FORCE OF RAINDROPS AND TRAP WATER, SLOWING ITS VELOCITY AND EROSIVE FORCE.
TRANSPORT TRANSPORT IS THE MOVEMENT OF SOIL PARTICLES IN MOVING WATER ACROSS THE SOIL SURFACE.	O	**INCREASE CROP RESIDUES OR VEGETATIVE COVER:** EACH PIECE OF CROP RESIDUE OR VEGETATION SERVES AS A LITTLE DAM, SLOWING RUNOFF AND INCREASING INFILTRATION AND SOIL DEPOSITION. **REDUCE SLOPE LENGTH AND STEEPNESS:** QUANTITY AND VELOCITY MOVING DOWNSLOPE DETERMINE THE AMOUNT OF SEDIMENT CARRIED WITH THE FLOW. REDUCING THE LENGTH OF SLOPE REDUCES THE QUANTITY OF WATER AVAILABLE FOR TRANSPORTING SOIL PARTICLES. REDUCING THE STEEPNESS OF THE SLOPE REDUCES THE VELOCITY OF THE MOVING WATER, WHICH REDUCES THE QUANTITY OF SOIL PARTICLES TRANSPORTED. **SLOW DOWN OR STOP WATER MOVEMENT:** AS THE VELOCITY OF WATER MOVING OVER THE SOIL SURFACE IS SLOWED, ITS ABILITY TO TRANSPORT SOIL PARTICLES IS REDUCED.

Deposition

Deposition is when the soil particle is no longer moved by the force of the water.

o

Provide a sink that traps sediment: Close-growing grasses, legumes, and small grains may be used on level ground to slow the movement of water below the critical speed, which will allow soil particles to settle out. Terraces, surface roughness, stripcropping, and water and sediment control basins

perform a similar function.

Factors such as organic matter content, crop residue cover, and soil surface roughness interact to determine how a soil resists the erosive force of water. These factors are used in the Revised Universal Soil Loss Equation to predict sheet and rill erosion.

Strategies for Water Erosion Control

The best strategy for water erosion control is to reduce soil detachment, if possible. This is the easiest and often most effective approach. Reducing transport can also be effective. The use of deposition to stop water erosion once it is occurring is frequently the most costly approach.

Some practices can be used. with more than one strategy. For example, crop residue or green cover crops can reduce detachment by limiting the impact of raindrop splash. Residue and vegetative cover can also reduce transport by slowing the rate of runoff. Residue cover of 30% reduces erosion by about 50%, compared to bare soil. Keeping sufficient cover on the soil is a principal erosion control practice. Desired amounts of residue can be achieved through the choice of tillage implement, speed of operation, and timing of tillage.

Reducing detachment can be achieved by a number of practices. Soil management to preserve organic matter, soil structure, and tilth aids in infiltration and thus reduces detachment. This may be as simple as preventing compaction by delaying tillage when the soil is too wet. Maintaining proper soil fertility levels, optimum soil pH, and crop health encourage plant growth and crop residue production, which helps maintain good soil tilth. The use of permanent vegetation in critical areas, such as in grass waterways and buffer strips, can protect the soil from detachment and slow runoff.

Reducing transport can also be achieved by a number of practices. Contour tillage and increasing soil surface roughness are examples. Tilling on the contour provides furrows perpendicular to the slope which act as collection basins and slow runoff. Roughening the soil surface at critical times with the proper tillage implement creates surface storage, enhances filtration, slows runoff, and can produce erosion-resistant clods. Reducing the length of slope also helps control soil erosion by reducing transport. Shortening slope length decreases runoff volume and velocity. Terraces and diversions are examples of structures that reduce slope length. Contour strips and divided slope farming also break slopes into segments and slow runoff and aid infiltration.

'Terraces have improved our wheat yields by at least 10 bushels.'

Terraces not only control soil erosion, they can also increase yields, says Keith Nelson, who farms in central Kansas. "Terraces and waterways keep water from running off our fields so fast when it rains, and this has increased our yields by about 10 bushels per acre. Terraces have literally saved our farm," he says.

Nelson has put both gradient and level terraces over the past four decades, and still has more land to terrace. Construction costs average about 50 cents per foot, and annual maintenance costs are minimal, he says. He always farms with the terraces, never over them.

THE SOIL CONSERVATION SERVICE (SCS) IN HIS COUNTY IS CURRENTLY OVERWORKED AND CAN'T GET ALL THE LAND STAKED OUT THAT NEEDS TERRACES. RATHER THAN WAIT, NELSON STAKES HIS OWN TERRACES USING SCS SPECIFICATIONS. HE BOUGHT A SMALL USED CASE DOZER AND IS USING IT TO BUILD HIS OWN TERRACES AND WATERWAY SYSTEM ON SOME LAND HE WANTS TO PUT INTO PRODUCTION.

NELSON PREFERS GRADIENT TERRACES OVER LEVEL TERRACES WHEREVER HE CAN PUT IN A WATER-WAY. WHERE A WATERWAY IS IMPRACTICAL, HE:LL PUT IN LEVEL TERRACES. "THE PROBLEM WITH LEVEL TERRACES IS THAT WATER CAN RUN OVER THEM IN A REAL HEAVY RAINSTORM.," HE SAYS.

EITHER WAY, TERRACES ARE AN IMPORTANT AND VALUABLE BEST MANAGEMENT PRACTICE, NELSON SAYS. HOW VALUABLE? "TERRACED GROUND SELLS FOR ABOUT $50 AN ACRE HIGHER THAN UNTERRACED GROUND AROUND HERE," HE SAYS.

WIND EROSION

DEFINITIONS

MOST PEOPLE FIRST NOTICE WIND EROSION WHEN THEY SEE DUST HIGH IN THE AIR. BUT-THIS "DIRTY AIR" IS ONLY A SMALL PERCENTAGE OF THE TOTAL WIND EROSION PROBLEM. MOST OF THE SOIL MOVEMENT OCCURS WITHIN A FOOT OF THE GROUND. WIND SPEED AS LOW AS 13 MPH ONE FOOT ABOVE THE SOIL SURFACE CAN CAUSE SOIL TO START BLOWING UNDER HIGHLY ERODIBLE FIELD CONDITIONS. ERODIBLE FIELD CONDITIONS CONSIST OF AN UNPROTECTED DRY SOIL SURFACE THAT IS SMOOTH, LOOSE AND FINELY GRANULATED. THE RATE OF EROSION MORE THAN TRIPLES AS WIND SPEED INCREASES FROM 20 TO 30 MPH.

PRINCIPLES OF WIND EROSION

WIND EROSION OCCURS ACCORDING TO THE FOLLOWING BASIC PRINCIPLES: 1) DETACHMENT, 2) TRANSPORT, AND 3) DEPOSITION. THESE ARE EXPLAINED IN THE GRAPHIC ON THE FOLLOWING PAGE.

WIND EROSION CAUSES SOIL PARTICLES TO MOVE IN THREE DIFFERENT WAYS:

1. SALTATION
2. SUSPENSION
3. SURFACE CREEP

FINE AND MEDIUM SAND-SIZED PARTICLES MOVE MAINLY BY **SALTATION.** THE WIND DISLODGES THESE SOIL PARTICLES **AND PROPELS THEM IN A BOUNCING OR JUMPING MANNER** ACROSS THE SOIL SURFACE. AS THEY BOUNCE, THE FORCE OF THEIR IMPACT DISLODGES OTHER PARTICLES, DETERIORATES VEGETATIVE RESIDUES, AND DAMAGES LIVING PLANTS. THE BOUNCING SOIL PARTICLES ARE RESPONSIBLE FOR SETTING IN MOTION OTHER SOIL PARTICLES IN AN AVALANCHING EFFECT AS EROSION MOVES DOWNWIND. SALTATION ACCOUNTS FOR 30-80% OF TOTAL SOIL MOVEMENT. THE WIDTH OF THE FIELD IS IMPORTANT BECAUSE THE AMOUNT OF SOIL MOVED INCREASES DOWNWIND UNTIL THE AIR IS SATURATED WITH SOIL PARTICLES.

THE IMPACT OF SALTATION FILLS AND "DIRTIES" THE AIR WITH TINY SOIL PARTICLES IN A PROCESS CALLED **SUSPENSION.** THESE PARTICLES, WHICH CONSIST PRIMARILY OF ORGANIC MATTER AND CLAY-SIZED PARTICLES, MAY BLOW FOR HUNDREDS OF MILES. SUSPENSION ACCOUNTS FOR ONLY A SMALL PART OF THE PRODUCTIVITY LOSS ATTRIBUTED TO WIND EROSION.

SURFACE CREEP DESCRIBES THE MOVEMENT OF LARGER SAND-SIZED PARTICLES ALONG THE SOD SURFACE. THESE PARTICLES ARE LOOSENED BY THE IMPACT OF SALTATION, BUT ARE TOO LARGE TO BE LIFTED OFF THE GROUND IN MOST WINDS. THEY MOVE BY ROLLING ON THE SURFACE. SURFACE CREEP CAN ACCOUNT FOR UP TO 25% OF THE SOIL MOVED BY WIND.

Wind Erosion

Principles		Strategies for Control
Detachment Detachment occurs when the force of the wind or the impact of moving soil particles causes stationary soil particles to move.	o	**Maintain vegetation or vegetative residues:** Vegetation reduces wind speed at the soil surface and prevents much of the direct wind force from reaching erodible soil particles. **Increase surface roughness:** Ridges and depressions formed by tillage alter wind speed by absorbing and deflecting part of the wind energy away from erodible soil. **Increase cloddiness:** Soil clods are more resistant to detachment by wind. Clods also provide shelter for other erodible materials. **Reduce field width along the prevailing wind direction:** Reduced field widths reduce the potential for soil avalanching. Barriers on the windward side of a field shelter a distance equal to about 10 times the height of the barrier from wind forces, reducing wind speed at the soil surface. **Reduce "knoll" effect:** Hilltops and slopes may cause windflows to converge, increasing wind force. Land leveling or benching can reduce the converging effect and reduce the wind velocity at the soil surface. **Increase soil moisture:** Moist soil is less susceptible than dry soil to detachment by wind. This is feasible only for irrigated production or where controlled drainage is practiced (especially for organic soils).
Transport Transport is the wind-driven movement of detached soil particles through the air or along the soil surface.	o	**Maintain vegetation or vegetative residues:** Reduces wind speed near the soil surface and prevents much of the direct wind force from transporting erodible soil particles. **Reduce field width along the prevailing wind direction:** Reduces windspeed at the soil surface for a distance about 10 times the height of the windward barrier. **Reduce "knoll" effect:** Land leveling or benching can slow wind velocity above the soil surface around knolls where wind forces converge.
Deposition Deposition occurs when soil particles are no longer being transported by the wind.	o	Maintain vegetation or vegetative residues: reduces wind speed and allows airborne soil particles to settle out and fall to the soil surface. Increase surface roughness: Rough terrain traps soil particles bouncing along the surface. Reduce field width along the prevailing wind direction: Reduces wind speed at the soil surface, allowing soil particles to settle out.

Factors Affecting Wind Erosion

/ Vegetative Cover
/ Soil cloddiness and clod stability
/ Surface roughness (ridge height)
/ Field length (unsheltered distance)
/ Residue type, height, and position relative to wind direction
/ Wind speed
/ Soil moisture

Strategies for Control of Wind Erosion

A protective vegetative cover on the soil surface is the simplest and surest way to control wind erosion. Crop residue or growing vegetation reduces wind velocity at the soil surface and protects soil particles from the full force of the wind. A vegetative cover also traps moving soil particles and limits the avalanching effect. The amount of residue required to lessen wind erosion varies with residue type, height, residual position in relation to wind direction, and soil type.

Several pieces of small-stemmed residue, such as . wheat, creates more friction to wind movement than fewer pieces of large-stemmed residue, such as corn.

Standing residue is more effective than flat residue at slowing wind speed at the soil surface. Standing wheat stubble, for example, is about nine times more effective in controlling wind erosion than the same amount of residue lying flat. The taller the residue, the greater its influence on reducing soil movement by wind' * A silhouette factor can be used to determine the effectiveness of standing residue to reduce wind erosion. The silhouette factor is calculated using the population density, height, and diameter of standing stubble.

Stable soil clods reduce wind erosion. Soil clods formed by tillage should be large enough to resist the erosive forces of the wind and protect other smaller material. Clod stability depends on soil moisture, density, texture, pH, and microbial activity. Coarse-textured soils do not readily form stable clods. These soils need to be moist and firm before tillage can produce stable clods. The soils that produce the most stable clods are loams, silty loams, clay loams, and silty clay loams. All clods are broken down and various rates by rainfall, weathering, tillage, equipment traffic, and abrasion by moving soil particles.

A rigid soil surface also helps reduce wind erosion. The upper edges of the ridges absorb and deflect part of the wind energy, while the depressions trap **saltating soil particles. Deep-furrow drills (hoe** drills) used in some areas to plant small grains usually produce deep enough ridges to provide some protection against wind erosion. The most effective ridge height is 2-10 inches. The orientation of rows should be perpendicular to the **wind whenever** possible.

AI wouldn't think of farming this ground any other way but with strips."

Wind erosion can be a fierce opponent in the wide open plains of western Nebraska, as elsewhere in the country. Carl Mortenson, Jr., who farms in the Nebraska Panhandle, has seen the devastation caused by wind erosion, and has implemented some low-cost yet effective best management practices to control the problem.

"My dad started farming in this country in 1919 and they had big, wide open fields," Mortenson says. "The ground blew something terrible in the '20s and '30s. Wind erosion really hurt their wheat yields, and it still does today where strips aren't used."

Mortenson began a system of stripcropping on all of his land, using strips of various widths, depending on the type of soil. He uses narrower strips on sandier soils. The effect on controlling wind erosion has been satisfying.

"We didn't have too much winterkill from blowing this year, and this was one of the worst years I've seen for winterkill. I wouldn't think of farming this ground any other way but with strips," he says.

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

CITIZEN CONTACT FORM

FOR BIOSOLIDS PROJECTS

☐ COMPLAINT ☐ INQUIRY ☐ OTHER

DATE OF REPORT: LOCATION: ____________________ DATE & TIME OF INCIDENT: ________________
(IF APPLICABLE)

LOCATION: ___________________________________ VEHICLE ID (IF POSSIBLE)__________________
(LICENSE #, PERMIT #, NAME ON VEHICLE, COLOR, ETC.)

(ADDRESS, COUNTY, ROAD #, SITE #, OTHER...)

NATURE OF INQUIRY: ____

____

____

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____

FOR MORE INFORMATION ON BIOSOLIDS MANAGEMENT, CONTACT:
CDPHE, BIOSOLIDS MANAGEMENT PROGRAM, (303) 692-3613 / FAX: (303) 782-0390
EPA REGION VIII, BIOSOLIDS COORDINATOR, (303) 312-6129 / FAX: (303) 312-7084

DO YOU WANT A CALL BACK? ☐ YES ☐ NO
IF YES, PLEASE GIVE TELEPHONE NUMBER(S): DAY: ( ) ______ - ________ EVES: ( ) _____ - ______

NAME: ____
ADDRESS: ____

FORWARDED TO CDPHE / EPA BY: NAME: ____
ADDRESS: ____
PHONE NUMBER: ____
FACILITY / CONTRACTOR NOTIFIED ON: DATE: _______
EVES: ( ) _____ - ______

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SECTION 2.10 C SETBACKS AND BUFFERS FOR LAND APPLICATION

Due to the sensitive nature of such areas as residential developments, streams and lakes, springs, flood plains, and public water supply wells, EPA established setbacks and buffers in the 1983 *Process Design Manual: Land Application of Municipal Sludge*, to ensure that these areas are protected from runoff, spray drift, and misapplication of biosolids. Table 2.10-1 shows the setbacks and buffers which must be considered prior to land application. Individual states may have their own requirements and you should consult your State Biosolids Coordinator. Table 2.10-2 provides a general description of potentially unsuitable areas for biosolids application.

Table 2.10-1. Suggested Setback Distances for Biosolids Application Areas.
(Excerpted from *Process Design Manual: Land Application of Municipal Sludge*
EPA-625/1-83-016, pp. 5-14 and 5-15.)

	Distance from Feature to Biosolids Application Site				
	10 to 90 m[*]		90 to 460 m[H]		>460 m[#]
Feature	Injection[**]	Surface	Injection[**]	Surface	Injection and Surface
Residential development	No	No	Yes	No	Yes
Inhabited dwelling	Yes	No	Yes	Yes	Yes
Ponds and lakes	Yes	No	Yes	Yes	Yes
Springs	No	No	Yes	Yes	Yes
10-year high water mark of streams, rivers, and creeks	Yes	No	Yes	Yes	Yes
Water supply wells	No	No	Yes	Yes	Yes
Public road right-of-way	Yes	No	Yes	Yes	Yes

[*] 50 to 300 feet.

[H] 300 to 1,500 feet.

[#] >1,500 feet.

[**] Injection of liquid biosolids or surface application of dewatered biosolids.

Table 2.10-2. Potentially Unsuitable Areas for Biosolids Application Which May Require Setbacks.

1) Land adjacent to subdivisions, schools, and other inhabited dwellings.
2) Areas bordered by ponds, lakes, rivers, and streams without appropriate buffer areas.
3) Wetlands and marshes.
4) Steep areas with sharp relief.
5) Undesirable geology (karst, fractured bedrock) (if not covered by sufficiently thick soil column).
6) Undesirable soil conditions (shallow, permafrost).
7) Areas of historical or archeological significance.
8) Other environmentally sensitive areas such as floodplains or intermittent streams, ponds, etc.
9) Rocky, nonarable land.

SECTION 2.11 C METALS AVAILABILITY VS. PH AND HOW YOUR BIOSOLIDS COMPARE TO THE NATIONAL AVERAGE

When applying biosolids to agricultural land, the uptake of metals by plants is controlled by a number of factors. One factor relates to the pH of the receiving soils. A distinction is made between mineral vs. organic soils and the relative cation-exchange-capacity (CEC) of each. For additional information regarding metal availability vs. pH, please refer to the listed reference.[2]

The 1988 National Sewage Sludge Survey determined the mean concentration of the ten regulated metals found in biosolids from POTWs throughout the country; this information is presented in Table 2.11.1. When viewing the table, the percentiles indicate what percentage of the biosolids included in the survey were at or below the listed pollutant values. For example, the 67th percentile means that 67 percent of the POTWs sampled had pollutant concentrations at or below the numbers presented in the middle column of the table.

Please note that the EPA Regions discourage municipalities from engaging in public competition over biosolids quality numbers. EPA recommends municipalities investigate the potential sources of contamination as metal levels move from the 67th toward the 98th percentile.

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[2] Kuhns, L.J., 1985. *Fertilizing Woody Ornamentals*. University Park, Pennsylvania. Penn State University, College of Agriculture, 16 pages.

Table 2.11-1.

Biosolids Quality Percentile Estimates
Based on National Sewage Sludge Survey, D.H. 8/93

Concentration in mg/kg Dry Weight

% Below	50%	60%	67%	70%	75%	80%	85%	90%	95%	98%	99%
As	5	6	8	9	10	13	16	22	33	54	75
Br	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.8	1.1	1.5	1.9
Cd*	4	5	6	7	8	10	12	16	25	41	56
Cr	44	63	83	93	115	147	196	278	469	847	1250
Cu	451	575	692	748	866	1021	1237	1570	2235	3331	4332
Hg	2	2	3	4	5	6	8	12	20	38	58
Mo	5	6	8	9	11	13	16	22	34	55	76
Ni	19	26	34	38	46	58	75	104	170	295	423
Pb	78	100	122	132	154	184	225	289	420	639	842
Se	3	4	5	6	7	8	10	12	18	28	37
Zn	746	956	1155	1250	1451	1717	2088	2663	3818	5735	7497

* CD-Database excluded one extreme outlier.

SECTION 2.12 C MICRO-NUTRIENTS vs. TOXIC METALS

One of the typical misconceptions about sewage biosolids is they contain a spectrum of toxic or "heavy" metals and may be bad for human health and the land on which they are applied. These metals are identified as pollutants or contaminants by 40 CFR Part 503. Many people know that several of these metals are plant nutrients essential for growth, but believe that the concentrations typically found in biosolids are too high to be beneficial to plants. It is the concentration of metals in biosolids that limits the areas and amounts of biosolids that can be land applied, under Part 503.

Some of the issues in the development of this regulation were: the scope of the regulation; pollutant coverage; pathways of exposure; target organisms; types of risks; acceptable level of risk; background pollutant levels; and pollutant limits.[3] In regard to micronutrients vs. toxic metals, the pollutant coverage, acceptable level of risk, and pollutant limits were key issues. The metal limits were developed after in-depth considerations of human health and the environmental risks associated with land application of sewage biosolids. The actual limits found in Tables 1 - 4 of Part 503.13 were set at levels that are within acceptable parameters of risk. If the metals concentration in the biosolids is below the limit for its respective use, it is believed that the biosolids will not harm either human health or the environment.

The following article was written by Gary Wegner, a Washington farmer, and presented at a Water Environment Federation (WEF) Conference on Biosolids in 1992. It presents a first-hand description of the benefits his crops have received from the application of biosolids. The crux of his article can be summarized in the following passage:

> "Eight essential plant nutrients are in the category we call 'heavy metals.' In fact, these nutrients are also essential 'human nutrients.' Just take a look at the label of a CENTRUM bottle. CENTRUM 'High Potency Multivitamin, Multimineral Formula,' from A to Zinc."[4]

Following the article is a reference section which may be helpful for additional information regarding micronutrients vs. toxic metals.

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[3] 40 CFR Part 503 Preamble, pages 15 - 18.

[4] Wegner, Gary. *The Benefits of Biosolids, from a Farmer's Perspective.*

THE BENEFITS OF BIOSOLIDS, FROM A FARMER'S PERSPECTIVE

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Wegner Ranch
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Reardan, WA 99029

(From WEF 1992 Biosolids Conference held in Portland, Oregon. Reprinted with Permission.)

I welcome you as a representative of American agriculture.

As professionals involved in wastewater management. YOU can now also be part of the food chain for our nation. I believe that is good.

Today, in the United States, about one percent of the nation's population produces ninety-five percent of the food needed by our country. People who grow food are usually called farmers. But farmers are just part of the food Aproduction and delivery@ chain in the U.S.A.

Does anyone know what percentage of the Chinese population is dedicated to food production? The answer is eighty percent. I bring you that statistic, not because I read it out of an old book. I bring it to you because I had a man from China visit my farm in 1991, and he verified that eighty percent is currently correct.

To get back to our own United States, if we were to tally up all of the people involved in the food Aproduction and delivery@ chain, we would include people who work to provide nutrients to enhance our nation's soils; we would include truck drivers who move products; we would include the people who work in a corn-flake factory; and we would include the pretty lady at the check-out counter of your favorite supermarket. Including all of those people in our food Aproduction and delivery@ chain, we would have about twenty percent of the U.S. population.

What have we discovered? In China, eighty percent of the population is dedicated to food production. In the U.S.A., eighty percent of the population is free to pursue the enhancement of society, develop public services and do many other things to improve our quality of life. The cheapest and most abundant food supply in the world is the key to the success of the United States.

With that introduction, I would like to share with you my perspective on the benefits of biosolids from my farm near Reardan, Washington.

Since the spring of 1988, the City of Spokane has applied biosolids to over twelve hundred acres of our farmland. Two hundred and fifty of those acres have received two application. Our average rainfall is fifteen inches per year. The dewatered biosolids are applied at an average rate of 4.5 dry tons per acre, (22.5 wet tons) per acre.

Organic Matter

The main reason I need biosolids is to provide organic matter to my soil. . . . BUT an application of biosolids does NOT increase my soil organic matter significantly when it is applied. The significant difference is seen in increased crop residue that results from higher crop yields that are grown on that soil, which provides Aincreased nutrient availability.@

Organic matter is an important soil constituent which influences virtually all chemical, biological and physical processes that occur in the soil.

Organic matter supplies plant nutrients during the mineralization process (microbial conversion of organic compounds to inorganic molecules that are available for plant uptake). This is a particularly important source of nitrogen (N), phosphorus (P) and sulfur (S). Organic matter also affects the solubility of other plant nutrients, such as zinc, (Zn), iron (Fe), copper (Cu), manganese (Mn) and P by forming organic complexes which increase their availability.

Organic matter also contributes to the cation exchange capacity of a soil, providing sites for the retention of basic cations such as potassium (K), calcium (Ca) and magnesium (Mg). Another important function of organic matter is its role as a Aglue@ in promoting soil aggregation and soil structure. Organic matter additions will often enhance water infiltration and water holding capacity, thereby increasing resistance to erosion.

Essential Plant Nutrients

Biosolids, which are derived from an organic source, provide a soil amendment that contains essential plant nutrients in a relatively balanced package. The major nutrient not provided in significant quantities by biosolids is potassium (K).

I find it interesting that eight essential plant nutrients are in the category we call Aheavy metals.@ In fact, these nutrients are also essential Ahuman nutrients.@ Just take a look at the label of a CENTRUM bottle, which reads: CENTRUM AHigh Potency Multivitamin, Multimineral Formula,@ from A to Zinc.

The soils on my farm are deficient in zinc (Zn). After I apply biosolids, my soils are NOT deficient in zinc. Biosolids is a vitamin pill for my crops. You can see the difference.

The best gauge of what has been accomplished by a change in a soil is to observe how plants respond. The same basic observations can be used for a flower in a flower pot, or a barley plant in my field. Has the Agreen leaf@ color changed? Has root growth been enhanced? Have the rate of growth and general vigor of the plant changed? Let's look at some examples of how plants have responded to biosolids on my farm.

There are many reasons why I believe that dryland grain land is an optimum location for utilizing biosolids. But before I elaborate, please let me make two points that I feel are extremely important.

Biosolids provide many benefits for farmland.

Biosolids benefit the city where they originate.

If you are involved in a wastewater program that considers Asludge disposal@ a Anecessary evil,@ your program will not work. Your mind-set must be to find the best possible option for the utilization of biosolids. This may not always be your lowest cost option, but it should be the best option for the environment and the long-term needs of the community you represent. The words "sludge, disposal, dumping," etc. must be eliminated from your vocabulary.

If you are involved in a wastewater program that considers biosolids distribution as a process that is enhanced by our involvement, then, and only then, are you on your way to a beneficial program. Your beneficial use program will be good for the farm that receives the biosolids and the nation that consumes the food that is grown on that land.

One long-term objective worth considering is what I call the ANutrient Transfer Plan@. The basic concept is a simple one. Remove lagoon solids from lagoons (dewater if cost effective) and haul it to the nearest secondary treatment plant, so that it can be Ahomogenized,@ in an anaerobic digester, and then dewatered and delivered to year-round agricultural utilization programs. This program would help to provide capacity in lagoons that now will not accept septage because of space limitations. This plan would assist small- and medium-sized communities with what is a very large, long-term problem. Emptying lagoons in this manner has several advantages:

1) Present an organized program for moving nutrients from lagoons to secondary treatment plants, and then to farmland.

2) Relieve the Aseptage crisis@ (septage with no place to go).

3) Encourage the production of Ahigh quality@ consistent biosolids (treated sewage sludge that meets all EPA requirements for land application), which facilitates a quality farmland application program.

4) Provide the best alternative for small- and medium-sized communities to empty their lagoons.

Non-irrigated (dryland) grain farms can be found in almost every part of this country. Normally the soils found on a dryland grain farm are depleted in the nutrients that can be provided with biosolids. The potential for Aperceived@ erosion and/or leaching are relatively low on a dryland grain farm. The crops raised on my dryland grain farm include, wheat, barley, oats and canola, but nationwide would also include corn, soybeans, grain sorghum, rye, triticale, millet, milo and rapeseed.

On September 3, 1991, I completed by harvest. My primary crop in 1991 was Steptoe barley. I had 425 acres of barley grown on land that had received biosolids at some time since 1988 and

315 ACRES OF BARLEY THAT HAD NEVER RECEIVED BIOSOLIDS. THE YIELD OF THE ABIOSOLIDS BARLEY@ WAS 1,080 POUNDS MORE PER ACRE THAN THE OTHER BARLEY. MY AVERAGE YIELD ON OUR DRYLAND ABIOSOLIDS BARLEY,@ ON 425 ACRES, WAS 3,840 POUNDS PER ACRE.

I BELIEVE THAT IF YOU WILL TAKE THE TIME TO REVIEW THE BASIC INFORMATION ABOUT SOIL NUTRITION AND THE COMPOSITION AND USES FOR BIOSOLIDS, YOU WILL BE ABLE TO UNDERSTAND WHAT MY BARLEY AND WHEAT PLANTS HAVE BEEN TELLING ME SINCE 1988:

> PLANTS LIKE BIOSOLIDS.

REFERENCES

ROBB, D.A. AND W.S. PIERPOINT. 1983. METALS AND MICRONUTRIENTS: UPTAKE AND UTILIZATION BY PLANTS.

SOIL SCIENCE SOCIETY OF AMERICA. 1972. MICRONUTRIENTS IN AGRICULTURE: PROCEEDINGS OF A SYMPOSIUM HELD AT MUSCLE SHOALS, ALABAMA, APRIL 20-22, 1971, AND COSPONSORED BY THE TENNESSEE VALLEY AUTHORITY AND THE SOIL SCIENCE SOCIETY OF AMERICA.

STEVENSON, F.J. 1986. CYCLES OF SOIL: CARBON, NITROGEN, PHOSPHORUS, SULFUR, MICRONUTRIENTS.

U.S. CROP REPORTING BOARD. NOVEMBER 1976. COMMERCIAL FERTILIZERS: CONSUMPTION OF COMMERCIAL FERTILIZERS, PRIMARY PLANT NUTRIENTS, AND MICRONUTRIENTS.

SECTION 2.13 C PART 258C CRITERIA FOR MUNICIPAL SOLID WASTE LANDFILLS

The regulations in 40 CFR Part 258 set requirements for the owners and operators (not generators) of municipal solid waste (MSW) landfills. The purpose of this reference sheet is not to summarize the entire Part 258 regulations, but to highlight key components and requirements that may be specific to the disposal of biosolids at a MSW landfill. Before disposal of biosolids in a MSW landfill, EPA Region VIII and the MSW landfill owner must require POTWs to conform to the following requirements and report the results from each test:

- Waste exhibiting free liquids, as determined by the paint filter test, cannot be deposited.
- Hazardous waste cannot be disposed of in a MSW landfill and the owners or operators of the landfill may require a TCLP verification analysis; PCB analysis may also be required.
- Owners and operators are required to prevent or control onsite populations of disease vectors using "techniques appropriate for the protection of human health and the environment."[5] Landfill owners may require documentation regarding the method of pathogen and vector attraction reduction.

Also, to be in compliance with Part 503 rules: (1) POTWs must ensure that biosolids disposed of at a MSW landfill are deposited within the active MSW "unit" and not in a separate unit, lagoon, or trench intended specifically for biosolids; and (2) the POTW must only send its biosolids to a MSW landfill that is in compliance with the requirements of Part 258.

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[5] 40 CFR 258.22.

SECTION 2.14 C BIOSOLIDS APPLICATION TO RANGELANDS

Biosolids application to agricultural land to increase crop yield has been practiced for several decades and its beneficial properties as a nitrogen fertilizer and soil conditioner have been well documented. Biosolids have also been applied to rangeland and, while not as extensively practiced and researched as its application to agricultural land, studies have demonstrated that it improves rangeland productivity. Unfortunately, very little of the research has focused on identifying potential adverse environmental impacts, specifically nitrate contamination of groundwater and surface water due to excess nitrate leaching and runoff. The following synopsis of some of the research findings provides some information which will serve municipalities in the design of biosolids to rangeland programs.

A summary of the significant data and results of 8 studies are listed in Table 2.14-1. The research study sites are limited to two sites in Colorado and two sites in New Mexico. The focus of the studies was to determine the optimum application rates that produced the greatest yield in native forage grasses without adverse impact on species diversity. The biosolids application quantities range from 0.0 to 90.0 Mg/ha (dry), and most soils were of medium texture (sandy loam, sandy clay loam). Most of the studies reported increases in vegetative productivity (some with increases in species diversity) as a result of the biosolids applications.

The New Mexico studies used application rates of 0, 22.5, 45 and 90 Mg/ha. One study reported most favorable vegetative growth at the 22.5 and 45 rates while another study reported 2- to 3-fold increase in forage production at the 45 and 90 Mg/ha rate. In contrast, the Colorado studies which used application rates of 0, 2.2, 4.5, 9, 11, 13, 18, 22, 27, 31, 34, and 36 reported enhanced vegetation at 4.5 Mg/ha with maximum vegetative growth at 11 Mg/ha. The Colorado studies indicate that enhanced forage production of rangeland occurs at much lower biosolid quantities than evaluated by the New Mexico studies. The 11 Mg/ha application rate may be providing the nitrogen needs of the grasses, and the higher yields achieved by rates greater than 11 Mg/ha may be due to the increased moisture provided by these higher biosolid rates.

The New Mexico studies did not evaluate nitrate leaching from biosolids applications; however, an additional study summarized in Table 2.14-2 reports changes in water flux in one of the New Mexico study sites as an indicator of potential leaching. The results of this study indicate that leaching is not believed to occur below 1.5 m depth in similar soils within the semiarid environment of the site. The problem of nitrate leaching was considered in the two Colorado studies. The problem of surface water contamination by nitrates in runoff was reported in three of the studies. The Fort Collins, CO studies (RBD and CDM, 1994) reported that an optimum application rate of 4.5 Mg/ha (dry) would enhance vegetative growth with minimum excess nitrate concentrations in soil. The Wolcott, CO study (Pierce, 1994) reported that application rates above 20 Mg/ha pose a potential hazard to surface waters by nitrate in surface runoff, while the New Mexico Sevilleta National Wildlife Refuge reported a reduction in surface water runoff at the 45 Mg/ha application rate.

EPA Region VIII recognizes that there is limited information on potential leaching of nitrates as a function of the application of biosolids to rangeland for vegetative growth enhancement. The Fort Collins, CO study indicates that application rates between 4.5 and 11 Mg/ha will prevent nitrogen from being the limiting factor for grassland productivity and will protect surface and groundwater from excessive nitrate leaching. The Agency will evaluate each

RANGELAND BIOSOLIDS APPLICATION ON A CASE-BY-CASE BASIS IN LIGHT OF THIS AND THE WOLCOTT, CO STUDY.

REFERENCES

AGUILAR, R., AND E.F. ALDON. SEASONAL WATER FLUX AND POTENTIAL FOR LEACHING IN A SEMIARID RANGELAND SOIL. IN: PROCEEDINGS OF THE FIFTH NATIONAL OUTDOOR ACTION CONFERENCE ON AQUIFER RESTORATION, GROUNDWATER MONITORING, AND GEOPHYSICAL METHODS. MAY 13-16, 1991. GROUNDWATER MANAGEMENT NO. 5, PP. 669-683.

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WHITFORD, W.G., E.F. ALDON, D.W. FRECKMAN, Y. STEINBERGER, AND L.W. PARKER. EFFECTS OF ORGANIC AMENDMENTS ON SOIL BIOTA ON A DEGRADED RANGELAND. JOURNAL OF RANGE MANAGEMENT, VOL 42, NO. 1, 1989, PP. 56-60.

Table 2.14-1. Summary of Research on Biosolids Application to Rangeland.

Reference	Geographic Location	Soil Profile	Plant Community	Mean Precip. (cm/yr)	Biosolids Type	Biosolids Loading (Mg/ha, dry)	Significant Results of Study
Gallier et al., 1993; Pierce, 1994	Wolcott, CO (central CO)	Not Reported	western wheatgrass, alkali bluegrass, Indian ricegrass	25	dewatered aerobically digested	0.0, 4.5, 9.0, 13.0, 18.0, 22.0, 27.0, 31.0, 36.0	Increase in species diversity with biosolids application. Increase in nitrogen concentration in soil profile with increasing application rates, but did not penetrate below 90 cm. Application rates above 20 Mg/ha pose a potential hazard for surface water contamination by nitrates.
RBD and CDM, 1994	Meadow Springs Ranch, Fort Collins, CO	sandy loam, sandy clay loam	blue grama, buffalo grass, western wheatgrass, fringed sage	38	dewatered anaerobic and composted	0.0, 2.2, 4.5, 11.0, 22.0, 34.0	Maximum vegetative growth was obtained at an application rate of 11 Mg/ha. An application rate of 4.5 Mg/ha (dry) of biosolids would increase vegetative growth and minimize excess nitrate concentrations in soil.
Aguilar and Loftin, 1991	Sevilleta National Wildlife Refuge, central NM	fine sandy loam, sloping alluvial fan	blue grama, hairy grama	20-25	dewatered	45.0	Reduction in runoff volumes due to biosolids water absorption and increased surface roughness. Nitrate concentrations in runoff were well below recommended NM standard of 10 mg/l-N.
Fresquez et al., 1991	Rio Puerco watershed, north-central NM	fine silty	snakeweed, blue grama	25	dewatered	0.0, 22.5, 45.0, 90.0	An increase of 2- to 3-fold in blue grama forage production was found for biosolids applications of 45 and 90 Mg/ha. A decrease in snakeweed yield was found.
Aguilar et al., 1992	Sevilleta National Wildlife Refuge, central NM	sandy loam, stable alluvial fan	blue grama, hairy grama	20-25	dewatered	45.0	Reduction in runoff volume due to water absorption of biosolids and increased surface roughness.
Dennis and Fresquez, 1989	Rio Puerco watershed, north-central NM	Not Reported	snakeweed, blue grama	25	dewatered	0.0, 22.5, 45.0, 90.0	High fungal populations and low fungal diversity found in soil due to increasing biosolids applications, thus improving the soil fertility.
Whitford et al., 1989	Rio Puerco watershed, north-central NM	Not Reported	blue grama	25	dewatered	1.0 biosolids (with 2.0 of woodchips and straw mulch)	No significant increase in soil biota.
Fresquez et al., 1990	Rio Puerco watershed, north-central NM	Not Reported	snakeweed, blue grama	25	dewatered	0.0, 22.5, 45.0, 90.0	Total foliar cover increased linearly with biosolids application quantities. Blue grama increase 2- to 3-fold. Biosolids applications of 22.5 and 45 Mg/ha produced the most favorable vegetative growth responses, whereas

Reference	Geographic Location	Soil Profile	Plant Community	Mean Precip. (cm/yr)	Biosolids Type	Biosolids Loading (Mg/ha, dry)	Significant Results of Study
							applications of 90 Mg/ha did not significantly increase yield.

Table 2.14-2. Summary of Research on Water Flux and Leaching Potential on Rangeland.

Reference	Geographic Location	Soil Profile	Plant Community	Mean Precip. (cm/yr)	Significant Results of Study
Aguilar and Aldon, 1991	Rio Puerco Watershed, west-central, NM	Querencia loam (sandy loam and sandy clay loam)	snakeweed, galetta-sand dropseed	25	The soil moisture content did not significantly increase at the depth interval of 161-170 cm during the 3-year period of study. Leaching due to saturated flow is not expected to occur below 1.5 m in similar soils within this semiarid environment. Noted change in specie. Decrease of noxious specie and saw species not seen for 50 years return.

SECTION 2.15 C GROUNDWATER MONITORING

Many POTWs may conduct groundwater monitoring as part of their standard operating procedures. The use of wastewater lagoons, biosolids drying/thickening lagoons, drying beds, storage piles, surface disposal sites or other related activities requires periodic groundwater monitoring due to the potential for groundwater contamination.

The standard EPA reference work for groundwater monitoring is *Practical Guide for Ground-Water Sampling* (EPA/600/2-85/104).

This document can be downloaded from the Internet at
http://www.epa.gov:80/swerust1/cat/pracgw.pdf

SECTION 2.16 C SUPPLEMENTAL REFERENCES

The following list of references may provide additional useful information for many of the topics presented in this handbook. There are references for both general and specific topics.

GENERAL

$ *Process Design ManualCSludge Treatment and Disposal*, EPA-625/1-79-011, September 1979.

$ *Process Design ManualCLand Application of Municipal Sludge*, EPA-625/1-83-016, October 1983.

$ *Technical Support Document for Land Application of Sewage SludgeC*Volume 1, EPA 822/R-93-001a, November 1992.

CONTROL OF PATHOGENS AND VECTOR ATTRACTION REDUCTION

$ *Environmental Regulations and TechnologyCControl of Pathogens in Municipal Wastewater Sludge*, EPA/625/10-99/006, September 1999.

$ *Technical Support Document for Reduction of Pathogens and Vector Attraction in Sewage Sludge*, EPA/822/R-93-004, November 1992.

$ *Environmental Regulations and TechnologyCControl of Pathogens and Vector Attraction in Sewage Sludge*, EPA/625/R-92/013, 1992.

AGRONOMIC RATE AND LOADINGS LIMITATIONS

$ *Soil Suitability and Site Selection for Beneficial Use of Sewage Sludge*, Manual 8, March 1990, Oregon State University Extension Service.

$ *Sewage Sludge Guidelines for Washington, Part TwoCSite Selection and Management, EB1431, Part ThreeCSample Problem and Worksheet for Calculating Sludge Application Rates*, EB1432, Washington State University Extension Service.

$ *Guide to Fertilizer Recommendations in Colorado*, XCM-37, 1990, Colorado State University Extension Service.

REGION VIII

Everything You Wanted To Know About Environmental Regulations … But Were Afraid To Ask, A Guide for Small Communities, April 1993. The document can be obtained by contacting Pauline Afshar at (303) 312-6267. A revsion of this document can be dowloaded at www.kdhe.state.ks.us/environment/evrythng.html.

Although it is direct ed toward Kansas, it includes applicable Federal statutes and regulations.

Environmental Guidance For Very Small Communities, Regulation Handbook, EPA 910/9-92-003.

U.S. EPA REGIONAL AND STATE BIOSOLIDS COORDINATORS

This list can also be dowloaded at www.bdmsinfo.com, EPA=s website on the Biosolids Data Management System.

U.S. EPA HEADQUARTERS/OFFICE OF RESEARCH AND DEVELOPMENT LAB CONTACTS

BIOSOLIDS CONTACTS

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SECTION 2.17 C SEARCHING FOR INFORMATION ON THE WORLD WIDE WEB

There is now so much information on the Web that it can seem overwhelming. When you do a search that retrieves thousands of documents, none of which are what you want, it can be frustrating. The Web has been described as a Abadly organized library@ but there are ways to bring order to it and find the information you want. A few tips will be provided. It is assumed that the user has one of the two most widely-used browsers, Netscape Navigator or Microsoft Explorer. Nothing in this section is meant as an endorsement of any commercial product or service.

There a number of search engines that you can use to help you find information. Because of its sheer size, complexity, and ever-changing nature, no search engine can cover the Web completely. Some provide more coverage than others. Two that are in common use are Northern Light (http://www.northernlight.com) and Alta Vista (http://www.altavista.com). No matter which search engine you use, it is a good idea to take a look at the Frequently Asked Questions (FAQs) and the Search Help or Search Tips so that you can maximize your searches.

A. If you know an exact phrase, put the phrase in quotes: **ACrime and Punishment@** will return documents that contain that phrase; the same words without the quotation marks (**Crime and Punishment**) will return documents that contain the word Crime and the word Punishment.

B. You can use **OR** to return documents that include any of the search words, such as **insulation OR fiberglass**. The word **NOT** can be used to exclude a word that must not appear in retrieved documents: **mariners NOT baseball**.

C. You can use a + (plus) to indicate words that must be present in retrieved documents and a - (minus) for those that must not be present:

+mariners -baseball

+recipes +ice cream -chocolate

D. The more words you use in your search, the more focused your results will be. A search for **French Alps ski resorts** will be more targeted than searching on **skiing**.

E. AWildcards@ can be used to replace multiple characters (*) or one character (%). For example:

chemi* will retrieve documents that begin with chemi (such as chemist, chemical, chemistry). **Psych*ist** will find documents that begin with **psych** and end in **ist** (such as psychologist, psychiatrist). **Gene%logy** will return documents containing words that begin and end as indicated, with one letter in between. This is useful for commonly misspelled words.

F. Many large web sites, such as government agencies or big companies, have a search engine to search that particular site. For example, EPA=s web site (http://www.epa.gov) is huge. If you know the title or a partial title of an EPA document, you can search for that phrase (by using quotes) and find the document you seek.

EXAMPLE SEARCH

To use an example, suppose you are doing a general search on biosolids. You could go to Northern Light and type in the word biosolids, without quotes. Over 9,000 documents will be returned, on a wide variety of topics related to biosolids. Northern Light will categorize these documents and put them in folders. In these case, some of the folder headings are Chemical fertilizers; Waste management; Sludge treatment; Recycling; Commercial sites, etc. By choosing one of the folders, the results will be more targeted and you will not have to browse through hundreds of documents to find what you seek.

Another way to focus the search would be to type in Afertilizer, biosolids@ to retrieve documents which contain both words. This search results in only 38 documents, a reasonable number to browse; again, the retrieved documents are sorted into folders.

A search on Afertilizer not chemical@ produces over 135,000 documents, while A+fertilizer +biosolids -chemical@ produces only 828. A search on AFertilizing with Biosolids@ (a document authored by Dan Sullivan of Oregon State University) yields less than 20 documents, including a link to Oregon State University and from there a link to the exact document being sought.

The principle illustrated here is simple. Make your searches as specific as you can. If the nature of your search is general, perhaps the results will give you clues to narrow it a bit and save some time.

Throughout this document references to the WWW are included. If you find interesting or useful sites, please forward those addresses to brobst.bob@epa.gov.