FINAL

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Compost and Water Quality
Technical Memorandum

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1. Introduction

This draft Technical Memorandum (TM) has been prepared as part of Task Order No. 51 –Statewide Compost Reconnaissance Study. The primary objectives of the study are to use available research to identify the risks and benefits of compost use as a standard California Department of Transportation (Caltrans) best management practice (BMP) to promote the growth of vegetation, decrease stormwater runoff, and provide erosion control; address concerns on compost use stemming from Water Quality Objectives (WQOs); identify the most appropriate and effective application methods and rates; and research the use of compost to achieve long-term low impact development (LID) goals outlined by the State Water Resources Control Board (SWRCB).

The purpose of this TM is to use available research to evaluate the effects that compost has on water quality.

The TM is organized as follows:

- Section 2 presents a background summary on the benefits and concerns associated with the use of compost.
- Section 3 describes the sources and potential pollutants associated with compost and current industry standards for controlling compost quality.
- Section 4 describes the different application methods of compost.
- Section 5 describes compost's effect on runoff and infiltration and discusses the "first flush phenomena" and how compost can influence pollutant concentration and loads in stormwater runoff.
- Section 6 presents a summary of findings associated with the use of compost and its effect on water quality.
- Section 7 includes a list of references used in this TM.

2. Background

Compost is the product resulting from the controlled biological decomposition of organic material (CIWMB 2008). Compost can increase soil porosity and water-holding capacity, improve soil structure and fertility, increase infiltration, reduce runoff, promote healthy and stable vegetation, reduce erosion, and, as a result, improve water quality.

Because of its benefits, compost application is considered for use as a standard BMP by Caltrans and other private and public entities. However, as compost contains decayed organic material, if it is not properly applied and the source material is not adequately screened, the potential exists for pollutant discharge into drainages and watercourses. Furthermore, the federal Clean Water Act (CWA) Section 401 requires that water quality standards not be exceeded.

Concern over the lack of guidance for quality control measures and that the use of compost could lead to the exceedance of water quality standards or a WQO has led to the reluctance to use compost as a Caltrans standard BMP.

In 2005, the California Integrated Waste Management Board (CIWMB) partnered with Caltrans; the University of California, Riverside Extension; the Association of Compost Producers; the US Composting Council (USCC); UC Cooperative Extension; Filtrexx; and Soil Control Laboratories to address the barriers preventing Caltrans from maximizing the use of compost. Working together, these various stakeholders developed a suite of compost specifications (Caltrans 2008a).

Although standard specifications have been developed, there still exists reluctance by both Caltrans and the SWRCB to incorporate compost into projects. Therefore, Caltrans has initiated the Statewide Compost Reconnaissance Study to further evaluate the benefits and risks associated with the use of compost and address the common barriers that prevent the use of compost as a standard Caltrans BMP.

3. Sources, Pollutants, and Industry Standards

As previously mentioned, there has been concern that the use of compost as a BMP could contribute pollutants to receiving waters via stormwater runoff and potentially lead to the exceedance of water quality standards or a WQO. This section identifies:

- Various sources of compost, including those most likely to be used by Caltrans;
- Potential pollutants associated with compost; and
- Current industry standards employed to control compost quality.

3.1 Compost Material

Compost material consists of three general stages: the input or feedstock, the intermediate process materials, and the output or final compost product. Each of these stages is described below.

3.1.1 Input

Compost originates from various organic sources, also known as feedstock materials, including, but not limited to (CIWMB 2008):

- Green Waste - Urban landscape waste generally consisting of leaves, grass clippings, weeds, yard trimmings, wood waste, branches and stumps, home garden residues, and other miscellaneous organic materials**.**
- Manure - Animal solid waste typically originating from racetracks, feedlots, swine and poultry facilities, and farms.
- Food Waste - All excess food, including surplus, spoiled, or unsold food such as vegetables and culls (lower quality vegetables or trimmings such as onion peels or carrot tops), as well as plate scrapings. Food waste is also referred to as food remnants, food residuals, or food scraps.
- Biosolids - The nutrient-rich organic materials resulting from the treatment of sewage sludge and wastewater.

Compost can also be composed of a mixture of feedstock materials, referred to as co-compost. In general, biosolids as a feedstock is not the sole source of a compost but rather a component of a co-compost, generally combined with green waste or food waste to increase the nutrient content.

3.1.2 Composting Process

Composting is the controlled process of rapidly decomposing organic matter using aerobic (oxygen-using) microorganisms at high temperatures (the active phase) followed by a more gradual decomposition of any remaining by-products at more moderate temperatures (the curing phase). Important factors for the compost process include maintaining good nutrient balance, correct moisture content and temperatures, and adequate aeration (CIWMB 2007).

3.1.3 Output

The composting process results in decomposed remnants of organic matter. The compost product is frequently used as a surface mulch, typically for erosion control, and as a soil amendment that holds moisture and provides nutrients to support and enhance plant growth. The chemical, biological, and physical composition of compost varies based on feedstock material and composting procedures. As a result, the Seal of Testing Assurance (STA) Program was established to monitor a variety of compost constituents and provide a method for ensuring compost quality. This program is discussed in more detail in Section 3.3.1.

3.2 Potential Pollutants Associated with Compost

Compost is a chemically and microbiologically complex product. Certain constituents, including nutrients (such as phosphorous and nitrogen), microbes, and complex ions facilitate plant establishment and growth. Other constituents are present as benign background chemicals and still others are generally considered harmful, such as metals and pathogens (including bacteria and viruses). Leaching of any of these constituents and subsequent discharge to receiving waters as a result of stormwater runoff has the potential to lead to exceedances of water quality standards. Nutrients and pathogens are of particular concern. These and other constituents of concern found in compost are discussed below.

3.2.1 Nutrients

As part of the 1972 CWA (Section 303(d)), the U.S. Environmental Protection Agency (EPA) has frequently listed streams for Total Maximum Daily Load (TMDL) designation for specific pollutants. Since 1995, nutrients have been one of the most frequently cited TMDL water impairing pollutants with 5,625 reported cases impairing 3,511 listed water bodies across the United States (Faucette 2008).

Nutrients, including nitrogen, phosphorous, potassium, calcium, and magnesium are common constituents in compost. In general, nutrients found in compost are in an organic form thus released slowly as the compost decomposes, increasing the opportunity for uptake by plants and potentially reducing downstream water pollution problems. Nutrients in this form are also less soluble and less likely to migrate into receiving waters. The content of these nutrient constituents is monitored under the STA Program and reported on the STA Compost Technical Data Sheet on both a dry weight basis (just like fertilizers) and on an "as received" or "wet weight" basis (because composts contain a much higher amount of moisture than do fertilizers) (USCC 2008c). Additional information about the STA Program is provided in Section 3.3.1.

3.2.2 Metals

Trace metals are elements whose concentrations are regulated due to the potential for toxicity to humans, animals, and plants. California law regulates heavy metals in compost from all commercial scale composting sources. Regulated metals include arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc.

Commercial compost producers routinely test for heavy metals as part of their quality control process (CIWMB 2007). The quantity of these elements is measured on a dry weight basis and expressed as milligram per kilogram (mg/kg) or parts per million. Many of these elements are actually needed by plants for normal growth, although in limited quantities. Therefore, measuring the concentrations of these elements can provide valuable management data relevant to the nutrient requirements of plants and subsequent application rates. Certain trace elements are also known to cause phytotoxic effects in plants (when available in very high quantities), and specific plant species are known to be more sensitive than others. These elements include boron, manganese, molybdenum, nickel, and selenium. However, these elements are not typically found in compost in detrimental quantities (USCC 2008c).

Most heavy metals are cations, carrying a positive charge. The soluble form of metal is thought to be more dangerous because it is more easily transported and more readily available to plants and animals. Soil particles and loose dust also carry charges. Most clay minerals have a net negative charge. Soil organic matter tends to have a variety of charged sites on their surfaces, some positive and some negative. The negative charges of these various soil particles tend to attract and bind the metal cations and prevent them from becoming soluble and dissolved in water.

Bioavailability of metals can be affected by sediment characteristics such as pH, redox potential, and organic content. Composting organic matter can bind metals and make them less bioavailable. Compost use as a soil amendment has been found to decrease the bioavailability of certain metals when compared with soil that did not contain compost material (EPA 1997). This has proved to be a cost-effective method of returning both urban and rural soils to productive use.

3.2.3 Pathogens

Pathogens are disease-causing organisms, including bacteria, viruses, fungi, helminths, and protozoa, which may be present in raw wastes or by-products. Both plant and human pathogens are found in living organisms and are present at some background level in the environment. Therefore, the composting process is regulated under Title 14, California Code of Regulations (CCR) to ensure that pathogens are eliminated or reduced to a level that is below the threshold where the danger of transmitting diseases will occur. Pathogens are inactivated or destroyed by elevated temperatures and antagonistic microbial scavenging over a period of time within the composting process (USCC 2008c).

3.2.4 Synthetic Organic Pollutants and Pesticides

Feedstock materials may contain a number of synthetic organic compounds or xenobiotics, including pesticides. Many different physical and chemical factors help determine the overall persistence of a pesticide. In general, composting provides an optimal environment for pesticide destruction. Water-soluble pesticides have a tendency to be “rinsed away” through a process called leaching, that is, the movement of a chemical within percolating water. Typically, leaching is of concern when the pesticide moves into groundwater or another location, posing an increased risk to humans and/or the environment. Many pesticides are not highly soluble in water, readily adsorbing onto the organic matter fraction. For this reason, use of composts in agricultural soils tends to reduce the threat of pesticide leaching losses (CIWMB 2008).

3.2.5 Soluble Salts

Soluble salts refer to the amount of soluble ions in a solution of compost and water. The concentration of soluble ions is typically estimated by determining the solution's ability to carry an electrical current (i.e., electrical conductivity). Plant essential nutrients are actually supplied to plants in a salt form. While some specific soluble salts, (e.g., sodium chloride), may be more detrimental to plants, most composts do not contain sufficient levels of these salts to be a concern in landscape applications. Plant species have a salinity tolerance rating and maximum tolerable quantities are known. Excess soluble salts can cause phytotoxicity to plants. Most composts have a soluble salt conductivity of 1.0 to 10.0 decisiemens per meter (dS/m), whereas typical conductivity values in soil range from 0 to 1.5 dS/m in most areas of the country (USCC 2008c). The content of soluble salt in compost is monitored as part of the STA Program.

3.3 Current Industry Standards to Control Potential Pollutants from Compost

A number of regulations, programs, and specifications have been established to control the quality of compost, thereby managing the discharge of potential pollutants in stormwater runoff.

3.3.1 U.S. Composting Council - Seal of Testing Authority Program

The STA Program is part of the USCC’s quality assurance process for compost. The STA Program is a compost testing, labeling, and information disclosure program created in 2000 and is the consensus of many leading compost research scientists in the United States. The science behind the development of the STA Program and the various tests that are used is contained in “Test Methods for the Examination of Composting & Compost” (TMECC) jointly published by the U.S. Department of Agriculture and the USCC. This publication includes a suite of physical, chemical, and biological tests. These were selected to help both compost producers and purchasers determine if the compost they are considering is suitable for the planned use, and to help them compare various compost products using a testing program that can be performed by a group of independent, certified labs across the United States and in Canada (USCC 2008c).

As part of the STA Program, all enrolled manufacturers or marketers (“participants”) must regularly sample and test their compost products based on production volumes, or as otherwise prescribed by the STA Program administrators for each facility they enroll. Participants must analyze compost for several parameters in addition to any and all testing required by applicable state and/or federal regulation (e.g., pathogens, heavy metals, pesticides, inerts, etc.) to ensure public health/safety and environmental protection. Testing parameters include:

- pH
- soluble salts

- nutrient content (total N, P_2O_5, K_2O, Ca, Mg)
- moisture content
- organic matter content
- bioassay (maturity)
- stability (respirometry)
- particle size
- pathogens (fecal coliform and salmonella)
- trace metals (Part 503 regulated metals, which include arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc)

The STA Program requires manufacturers to disclose analysis results of required testing parameters in accordance with specified reporting protocols. Test results are submitted to the USCC on standard compost technical data sheets (i.e., CTDSs) and include numerical results as well as discussions associated with the evaluation and interpretation of various testing parameters. The STA Program does not establish thresholds or maximum limits for any of the testing parameters; however, a producer must certify that it is in compliance with all applicable local, state, and federal regulations with respect to the certified compost product(s) and it must remain compliant to remain in the STA Program.

3.3.2 Federal Regulation of Compost

Federal rules regarding compost include biosolids regulation in Section 40, Code of Federal Regulations (CFR) Part 503 - Standards for Class A Biosolids. According to 40, CFR Part 503, biosolids that are to be land applied must meet strict regulations and quality standards. The Part 503 rule governing the use and disposal of biosolids contains numerical limits for metals in biosolids, pathogen reduction standards, site restrictions, crop harvesting restrictions and monitoring, and record keeping and reporting requirements for land-applied biosolids, as well as similar requirements for biosolids that are surface disposed or incinerated. Most recently, standards have been proposed to include requirements in the Part 503 Rule that limit the concentration of dioxin and dioxin-like compounds in biosolids to ensure safe land application (CWWA 2008). Biosolid-derived compost must also comply with these requirements.

3.3.3 California Regulation of Compost

Title 14, CCR, Division 7, Chapter 3.1, Article 7 sets forth requirements for the manufacture and distribution of compost. With respect to pollutant concentrations in compost, Title 14, CCR sets forth maximum acceptable metal concentration limits and pathogen reduction requirements for compost. The CCR includes sampling and analysis requirements based on feedstock materials to meet the established maximum metal concentrations.

3.3.4 Caltrans Compost Specification

In addition to the specification in Title 14, CCR, Caltrans has established standards for the type and use of compost. As part of the Landscape Architecture Specifications, procedures and requirements are set forth for incorporating compost onto slopes 4:1 Horizontal to Vertical (H:V) or flatter. The compost producer must be fully permitted as specified under the CIWMB, and/or applicable state and local agencies, and must be a participant in the USCC STA Program.

Compost may be derived from any single material or mixture of any of the following feedstock materials:

1. Green material consisting of chipped, shredded, or ground vegetation; or clean processed recycled wood products
2. Biosolids
3. Manure
4. Mixed food waste

Compost must not be derived from mixed municipal solid waste and must be reasonably free of visible contaminants. Compost must not contain paint, petroleum products, pesticides, or any other chemical residues harmful to animal life or plant growth. Compost must not possess objectionable odors. Metal concentrations in compost must not exceed the maximum metal concentrations listed in Title 14, CCR, which are listed in Table 3-1.

Table 3-1 Maximum Acceptable Metal Concentrations

Constituent	Concentration (mg/kg) on dry weight basis
Arsenic (As)	41
Cadmium (Cd)	39
Chromium (Cr)	1200
Copper (Cu)	1500
Lead (Pb)	300
Mercury (Hg)	17
Nickel (Ni)	420
Selenium (Se)	36
Zinc (Zn)	2800

The specification also provides requirements for the physical and chemical properties of compost (see Table 3-2), including pH, soluble salts, moisture content, organic matter content, maturity, stability, particle size, passing of fecal coliform test, passing of salmonella test, and physical/man-made contaminant content requirements (Caltrans 2008a).

Table 3-2 Physical/Chemical Requirements for Compost

Property	Test Method	Requirement
pH	*TMECC 04.11-A, Elastometric pH 1:5 Slurry Method, **pH Units**	6.0–8.0
Soluble Salts	TMECC 04.10-A, Electrical Conductivity 1:5 Slurry Method **dS/m (mmhos/cm)**	0-4.0
Moisture Content	TMECC 03.09-A, Total Solids & Moisture at 70+/- 5 deg C, **% Wet Weight Basis**	30–60
Organic Matter Content	TMECC 05.07-A, Loss-On-Ignition Organic Matter Method (LOI), **% Dry Weight Basis**	30–65
Maturity	TMECC 05.05-A, Germination and Vigor Seed Emergence Seedling Vigor **% Relative to Positive Control**	 80 or Above 80 or Above
Stability	TMECC 05.08-B, Carbon Dioxide Evolution Rate **mg CO_2-C/g OM per day**	8 or Below
Pathogen	TMECC 07.01-B, Fecal Coliform Bacteria **< 1000 MPN/gram dry wt.**	Pass
Pathogen	TMECC 07.01-B, Salmonella < **3 MPN/4 grams dry wt.**	Pass
Physical Contaminants	TMECC 02.02-C, Man-made Inert Removal and Classification: Plastic, Glass and Metal, **% > 4mm fraction**	Combined Total: < 1.0
Physical Contaminants	TMECC 02.02-C, Man-made Inert Removal and Classification: Sharps (Sewing needles, straight pins and hypodermic needles), **% > 4mm fraction**	None Detected
Fine compost must also comply with the following:		
Particle size	*TMECC 02.02-B, Sample Sieving for Aggregate Size Classification **% Dry Weight Basis**	95% Passing, 5/8 inch 70% Passing, 3/8 inch
Medium compost must also comply with the following:		
Particle size	* TMECC 02.02-B, Sample Sieving for Aggregate Size Classification **% Dry Weight Basis**	100% Passing, 3 inch 90% - 100% Passing, 1 inch 70% - 100% Passing, 3/4 inch 40% - 60% Passing, 1/4 inch Maximum length 6 inches

*TMECC refers to "Test Methods for the Examination of Composting and Compost," published by the U.S. Department of Agriculture and the U.S. Composting Council (USCC).

Similar to the compost specification, Caltrans has established the soil amendment specification that requires soil amendment used on Caltrans projects to consist of compost produced from green material, biosolids, manure, or mixed food waste, and to meet the environmental health standards of Title 14, CCR.

In addition, the Caltrans mulch specification allows the designer to select and specify mulch from a list of materials, including green material, tree bark, wood chips, and shredded bark, and requires that green material mulch be produced by a compost producer that belongs to the USCC STA Program. This specification also requires that compost materials be in conformance with Title 14, CCR.

3.4 Typical Composition of STA-Certified Compost

STA Program participants are required to test for a number of parameters, as discussed in Section 3.3.1. Test results are then submitted to the USCC on SCTDs and include numerical results as well as discussions associated with the evaluation and interpretation of various testing parameters. STA-participant suppliers were contacted to acquire information on compost product chemical composition, for typical composts that could be used by Caltrans. Table 3-3 summarizes this information.

Measures of select pathogens (salmonella and fecal coliform) and trace metals are below EPA Class A standards for all composts detailed in the provided technical data sheets. Other tested parameters do not have EPA Class A standards available for comparison. Although parameter values in Table 3-3 do not differ significantly between green waste and food waste feedstocks, the biosolids mix had the highest values of ammonia, phosphorous, and sulfate values at 3900, 11,000, and 2500 mg/kg, respectively. The biosolids mix also resulted in the highest nutrient content (N+P2O5+K20) and organic matter content of all of the compost mixes. The organic matter content, at 74.8 percent, is well above the allowed range of 30 to 65 percent outlined in the Caltrans Compost Specifications (Table 3-2).

Table 3-3 Parameter Values for Compost Based on Feedstock Material

		Green waste (Supplier 1)	Green waste (Supplier 2)	Green waste (Supplier 3)	Food waste (Supplier 4)	90% Res/Comm Green waste, 10% grape pomace & manure (Supplier 5)	100% Yard Trimmings (Supplier 6)	Green waste (Supplier 7)	Biosolids Mix[1] (Supplier 8)	Manure Mix [2] (Supplier 8)	Caltrans Compost Specification Standards
Nutrients (dry wt.)	Total Nitrogen (%)	2.10	1.50	2.00	1.60	1.30	1.60	2.30	2.3	1.50	NA
	Ammonia (mg/kg)	960.00	140.00	480.00	230.00	340.00	360.00	1100.00	3900.00	520.00	NA
	Nitrate (mg/kg)	0.11	2.30	0.11	5.10	0.11	2.00	0.11	0.11	5.40	NA
	Org. Nitrogen (%)	2.00	1.50	2.00	1.60	1.30	1.60	2.20	1.90	1.40	NA
	Phosphorous (P) mg/kg	4300.00	1900.00	3800.00	2000.00	2800.00	4900.00	3900.00	11000.00	3900.00	NA
	Potassium (K) mg/kg	14000.00	8200.00	13000.00	9500.00	8400.00	7700.00	11000.00	7200.00	17000.00	NA
	Calcium (%)	2.00	2.20	2.20	1.30	1.50	2.40	2.80	2.70	2.60	NA
	Magnesium (%)	0.67	0.63	0.74	0.36	0.53	0.59	0.41	0.53	0.66	NA
	Sulfate (mg/kg)	890.00	380.00	350.00	510.00	900.00	770.00	2.60	2500.00	380.00	NA
	Soluble Salts (dS/m)	7.50	3.50	5.60	4.10	4.60	4.20	7.40	8.10	6.10	**0-4.0**
	Sodium (Na) %	0.19	0.13	0.45	0.08	0.14	0.22	0.47	0.12	56.00	NA
	Chloride (%)	0.52	0.25	0.46	0.23	0.27	0.27	0.72	0.24	0.36	NA
	pH	7.33	7.05	7.86	6.33	6.75	7.78	8.04	6.65	8.46	**6.0–8.0**
	Organic Matter (%)	47.20	53.10	48.20	64.20	51.50	36.00	55.00	74.80	38.40	**30–65**
	Organic Carbon (%)	23.00	30.00	27.00	25.00	24.00	20.00	31.00	39.00	21.00	NA
	Ash (%)	52.80	46.90	51.80	35.80	48.50	64.00	45.00	25.20	61.60	NA
	C/N Ratio	11.00	20.00	14.00	15.00	18.00	13.00	14.00	17.00	14.00	NA
Metals (dry wt.)	Aluminum (mg/kg)	9500.00	6500.00	8400.00	3300.00	6000.00	7400.00	6300.00	4000.00	5300.00	NA
	Arsenic (mg/kg)	3.60	3.10	5.20	2.50	8.30	6.20	8.30	1.10	3.10	**41**[3]
	Cadmium (mg/kg)	1.20	2.90	2.00	1.40	2.10	2.00	2.60	4.70	3.20	**39**[3]
	Chromium (mg/kg)	29.00	63.00	31.00	12.00	25.00	30.00	29.00	27.00	15.00	**1200**[3]
	Cobalt (mg/kg)	7.40	7.10	7.30	2.60	6.90	6.60	4.40	2.30	4.60	NA
	Copper (mg/kg)	62.00	75.00	54.00	33.00	62.00	84.00	96.00	440.00	63.00	**1500**[3]
	Iron (mg/kg)	13000.00	12000.00	14000.00	7800.00	12000.00	12000.00	9100.00	17000.00	10000.00	NA
	Lead (mg/kg)	35.00	30.00	70.00	9.30	68.00	71.00	24.00	41.00	24.00	**300**[3]
	Manganese (mg/kg)	370.00	300.00	400.00	150.00	500.00	390.00	260.00	140.00	240.00	NA
	Mercury (mg/kg)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.99	<1.0	**17**[3]
	Molybdenum (mg/kg)	<1.0	3.40	1.70	1.50	1.30	1.80	3.00	9.80	4.20	**18**[3]
	Nickel (mg/kg)	34.00	45.00	43.00	9.00	31.00	31.00	15.00	75.00	12.00	**420**[3]
	Selenium (mg/kg)	<1.0	2.10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**36**[3]
	Zinc (mg/kg)	200.00	160.00	220.00	99.00	260.00	270.00	210.00	540.00	190.00	**2800**[3]
Patho-gens	Fecal Coliform (MPN/g)	56.00	14.00	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	1.80	**< 1000 MPN/g**[3]
	Salmonella (MPN/4g)	<3	<3	<3	<3	<3	<3	<3	<3	<3	**< 3 MPN/4g**[3]

Notes: NA indicates that no threshold has been developed for the constituent.

1. Biosolids Mix - 36% Green waste, 20% Zoo Doo, 44% biosolids
2. Manure Mix - 55% Green waste, 15% wood, 30% Horse Manure
3. EPA Class A Standards

4. Application Methods

Compost can be used or applied in a number of ways. Common applications for compost and those most likely to be used by Caltrans include incorporating compost into soil as an amendment to increase stormwater infiltration and facilitate vegetation growth; installing compost blankets for erosion control; utilizing compost filter socks for erosion and sediment control; and applying compost as a mulch for soil protection. These application methods are further described below.

4.1 Compost as a Soil Amendment

Compost is incorporated into soil within the root zone to improve soil quality, plant viability, and soil hydraulic conductivity (USCC 2008b). Compost can be incorporated into soil at different depths. The amount of compost used and depth to which it is incorporated is dependent on the existing soil characteristics. The Caltrans compost specification for soil amendment (similar to the other compost-related specifications) requires soil amendment used on Caltrans projects to be compost produced from green material, biosolids, manure, or mixed food waste feedstocks and to meet the environmental health standards. This specification does not go into detail regarding application methods/rates.

4.2 Compost Blanket

A compost blanket is a layer of loosely applied compost or composted material that is placed on the soil surface in disturbed areas to control erosion and retain sediment resulting from sheetflow runoff. It can be used in place of traditional sediment and erosion control BMPs such as mulch, netting, or chemical stabilization. When properly applied, the erosion control compost forms a blanket that completely covers the ground surface. This blanket controls stormwater erosion by (1) presenting a more permeable surface to the oncoming sheetflow, thus facilitating infiltration; (2) filling in small rills and voids to limit channelized flow; and (3) promoting establishment of vegetation on the surface. Composts used in compost blankets are made from a variety of feedstocks, including municipal yard trimmings, food residuals, separated municipal solid waste, biosolids, and manure (USCC 2008a).

The compost blanket can be vegetated by incorporating seeds into the compost before it is placed on the disturbed area (recommended method) or the seed can be broadcast onto the surface after installation (Risse and Faucette 2001).

In general, compost blankets have several advantages over more traditional stormwater BMPs such as geotextile blankets. Advantages provided by compost blankets include the following (Alexander 2003; Faucette 2004):

- The compost retains a significant volume of water, which helps reduce runoff, prevents or reduces sheet and rill erosion, and aids in establishing vegetation.
- The compost blanket acts as a buffer to absorb rainfall energy, which prevents soil compaction and crusting, and facilitates rainfall infiltration.

- Compost blankets facilitate plant growth by capturing and retaining moisture and providing a suitable microclimate and nutrients for seed germination.
- Compost stimulates microbial activity, which increases decomposition of organic matter, increases nutrient availability for plants, and improves the soil structure.
- Compost can remove pollutants, such as heavy metals, nitrogen, phosphorous, oil and grease, and fuel, from stormwater, thus improving downstream water quality (W&H Pacific 1993; EPA 1998).

The Caltrans compost blanket specification includes placing a thin layer of coarse compost to an area and then applying the seed via hydroseeding or dry/hand application. If applied via hydroseed, fiber and stabilizing emulsion are to be applied as well. The compost protects the seed from the elements promoting germination; provides nutrients to enrich the soil; and acts as a mulch; reducing competition from annual weed species, reducing stormwater runoff, and helping conserve soil moisture.

4.3 Compost Socks

A compost filter sock is a type of contained compost filter berm. It is a mesh tube filled with composted material that is typically placed perpendicular to sheetflow runoff along the perimeter of a site, or at intervals along a slope, to capture and treat stormwater and control sediment in disturbed areas. The compost filter sock, which is oval to round in cross section, provides a three-dimensional filter that retains sediment and other pollutants (e.g., suspended solids, nutrients, and motor oil) while allowing the cleaned water to flow through (Tyler and Faucette 2005). The filter sock can be used in place of a traditional sediment control BMP such as a silt fence or straw bale barrier. Composts used in filter socks are made from a variety of feedstocks, including municipal yard trimmings, food residuals, separated municipal solid waste, biosolids, and manure.

Filter socks are flexible and can be filled in place or filled and moved into position, making them especially useful on steep or rocky slopes where installation of other erosion control BMPs is not feasible. There is greater surface area contact with soil than typical sediment control devices, thereby reducing the potential for runoff to create rills under the device and/or create channels carrying unfiltered sediment.

They can also be used on pavement as inlet protection for storm drains and to slow water flow in small ditches (USCC 2008a).

Compost filter socks can be vegetated or unvegetated. Vegetated filter socks can be left in place to provide long-term filtration of stormwater as a postconstruction BMP. The vegetation grows into the slope, further anchoring the filter sock. Unvegetated filter socks are often cut open when the project is completed, and the compost is spread around the site as soil amendment or mulch. The mesh sock is then disposed of unless it is biodegradable. Several advantages of the filter sock over traditional sediment control BMPs, such as a silt fence, include (USCC 2008a):

- Installation does not require disturbing the soil surface, which reduces erosion.
- It is easily removed.
- The operator must dispose of only a relatively small volume of material (the mesh).

- Cost savings can be obtained either through reduced labor or disposal costs.
- The compost retains a significant volume of water, which helps prevent or reduce rill erosion and aids in establishing vegetation on the filter sock.
- The mix of particle sizes in the compost filter material retains as much or more sediment than traditional perimeter controls, such as silt fences or hay bale barriers, while allowing a larger volume of clear water to pass through. Silt fences often become clogged with sediment and form a dam that retains stormwater, rather than letting the filtered stormwater pass through.
- In addition to retaining sediment, compost can retain pollutants such as heavy metals, nitrogen, phosphorous, oil and grease, fuels, herbicides, pesticides, and other potentially hazardous substances, which improves the downstream water quality (EPA 1998).
- Nutrients and hydrocarbons adsorbed and/or trapped by the compost filter can be naturally decomposed through bioremediation by microorganisms found in the living compost matrix (EPA 1998).

Caltrans recently released a specification for this compost application method (Caltrans 2008a).

4.4 Mulch

Mulch is a layer of organic material spread over the bare surface of soil to block the loss of moisture and to discourage the growth of weeds (CIWMB 2008). The Caltrans compost specification for mulch allows the designer to select and specify mulch from a list of materials, including green material, tree bark, wood chips, and shredded bark, and requires that green material mulch be produced by a compost producer that belongs to the USCC STA Program and consist of compost materials in conformance with Title 14, CCR.

4.5 Erosion Control

Many studies have shown that compost can be highly effective for reducing and preventing erosion on an exposed slope. The following specifications detail Caltrans application methods, including compost for use as erosion control.

4.5.1 Caltrans Compost Specifications, Erosion Control Type C

Erosion Control (Type C) work includes applying seed, fiber, stabilizing emulsion, straw, and compost to “fill” slopes. The seed, fiber, and stabilizing emulsion are typically mixed in a slurry with water and applied from a hose attached to a hydroseed truck. Compost can either be applied together with the other materials in the slurry, or it can be dry-applied as a separate step in the process. While a separate dry application of compost has a higher labor cost, the material cost of the bulk (dry) compost can be up to one-tenth the cost of the bagged compost required for hydroseed application.

4.5.2 Caltrans Compost Specifications, Erosion Control Type D

Erosion Control (Type D) work includes applying seed, fiber, stabilizing emulsion, and compost to “cut” or “fill” slopes. The seed, fiber, and stabilizing emulsion are typically mixed in a slurry with water and applied from a hose attached to a hydroseed truck. Compost can either be applied together with the other materials in the slurry, or it can be dry-applied as a separate step in the process. While a separate dry application of compost has a higher labor cost, the material cost of the dry compost can be up to one-tenth the cost of the bagged compost required for hydroseed application.

4.6 Drill Seed

Drill seeding involves placing seed in the soil with a device similar to that used by farmers to plant agricultural crops. Placing the seed in the soil offers greater protection from the sun, wind, birds, and like items that inhibit seed germination. To help improve soil fertility, and reduce erosion by high winds and rainfall, the Caltrans specification for drill seed calls for a thin layer of compost and stabilizing emulsion to be applied to the soil surface after the drill seeding work is complete.

5. Stormwater and Water Quality

The use of compost as a method to amend soil properties or provide erosion control will also affect stormwater infiltration and runoff quality. These topics are discussed below.

5.1 Runoff and Infiltration

Unlike most other stormwater BMPs, compost has significant water-holding capacity, so that low-to-medium intensity and duration rain events may produce no runoff (Persyn et al. 2004). Those that do produce runoff produce less, take longer before runoff starts, and take longer to reach peak flow (Glanville et al. 2003). In research performed by Dr. William Sopper of Pennsylvania State University, compost (and biosolids) were applied to a gravely site, possessing a low pH and organic matter content, and contaminated with zinc. In relation to infiltration and runoff, the study found that the physical structure of the compost-amended soil increased soil porosity and moisture infiltration, thus reducing runoff (CCREF n.d.). Though studies agree that the use of compost increases water-holding capacity and reduces runoff, the extent is dependent on the amount and type of application method applied.

Infiltration is a key component in nutrient and sediment reduction in storm runoff, as shown in a recent study looking at a series of compost applications (Claassen and Carey 2004). The results of this study and the impacts of infiltration on nutrient and sediment losses are discussed further in Section 5.3.1. The effect of compost type and method of application on runoff volumes and infiltration will be further evaluated in the Compost and LID technical memorandum.

5.2 First Flush Phenomenon

First flush is the concept that pollutants are more concentrated in runoff at the beginning of a rainfall event than in the later parts of a rainfall event. The concept can be applied to the mass discharge of contaminants (e.g., mass first flush) or the concentration (e.g., concentration first flush). Pollutant reduction occurs because the pollutant mass may be washed out of the site, or may be diluted by higher runoff flow rate as the storm progresses. While most researchers believe that the first portion of runoff does have higher contaminant concentrations, opinions vary as to the importance of the increased concentrations, and whether the actual mass of the first flush is a significant portion of the total runoff mass (i.e., total pollutant loading) (Caltrans 2005).

The first flush or initial stormwater discharge, from a site with compost application has the potential to carry greater concentrations of water-soluble pollutants. Respondents interviewed as a part of the literature review (Caltrans 2008b) found that although total nutrient load is decreased after a first rain, the initial release may be small, but concentrated. However, due to the increased water-holding capacity of compost and depending on type of application, there may be no runoff except in extreme storm events; therefore, total pollutant loading may be lower even if the first-flush concentration is higher.

Although no specific studies on compost relating to the first flush are available thus far, several studies have shown that compost erosion control blankets, when used for slope stabilization, result in reduced storm runoff volume relative to other conventional erosion control methods such as hydromulch and straw mulch. Published research found that straw mulch resulted in 200 percent more runoff volume and hydromulch resulted in 137 percent more runoff volume than compost erosion control blankets when used for slope stabilization purposes (Faucette 2008).

5.3 Pollutant Concentration/Annual Load

Many variables must be considered when evaluating the effect of compost on pollutant concentration and/or load in stormwater. These variables include:

- Initial compost characteristics (including pollutant concentration, maturity, stability, moisture content, and particle size)
- Study location (field versus lab)
- Inflow conditions (sheetflow versus concentrated flow)
- Type of feedstock material
- Type of compost application
- Duration of study

Research conducted on available information associated with compost and water quality is summarized below.

5.3.1 Comparison of Compost to Traditional Erosion Control Methods

Compost vs. Topsoil

The nutrient and metals content of some composts are higher than some topsoils. This, however, does not necessarily translate into higher metals and nutrient concentrations or loads in stormwater runoff. A recent study by Glanville, et al. (2003) compared the stormwater runoff water quality from compost- and topsoil-treated plots. They found that although the composts used in the study contained statistically higher metals and nutrient concentrations than the topsoils used, the total masses of nutrients and metals in the runoff from the compost-treated plots were significantly less than plots treated with topsoil.

Compost Blanket and Filter Berm vs. Hydroseed and Silt Fence

Likewise, Faucette et al. (2005) found that nitrogen and phosphorous loads from hydroseed and silt fence treated plots were significantly greater than plots treated with compost blankets and filter berms. This study also concluded that using compost of low nutrient content has the added benefit of releasing less phosphorous and nitrogen than hydroseeding, hydromulching, and seeded straw mulches, all common erosion control BMPs (Faucette et al. 2005).

Compost-Amended Vegetated Filter Strips vs. Non-Compost-Amended Vegetated Filter Strips

A study conducted by the Washington Department of Transportation revealed that both pollutant concentrations and loads in highway runoff for all pollutants studied (total suspended solids, total copper, dissolved copper, total lead, dissolved lead, total zinc, dissolved zinc) except total phosphorous and total dissolved solids are significantly reduced when using Compost Amended Vegetated Filter Strips (CAVFS) in comparison to filter strips without a compost amendment. In addition, the strips with the compost amendment exhibited decreased flow volumes and flow rates as compared to filter strips without compost. When overall reduction of runoff volume is factored in, the CAVFS were shown to reduce all pollutant loads studied (Salisbury 2006).

Compost Erosion Control Blankets vs. Other Erosion Control Methods

Compost erosion control blankets supply nitrogen and phosphorous in organic form. Organic nutrients are slow release, helping to promote and sustain plant growth, and are less mobile in runoff than the inorganic nutrient forms typically found in commercial fertilizers. Thus, compost erosion control blankets have been found to release much less nitrogen and phosphorous in storm runoff when compared to conventional methods of erosion control (Faucette 2008). Additionally, as discussed in Section 5.2, compost erosion control blankets have been shown to absorb considerably more rainfall, leading to a much greater reduction in runoff volumes and peak discharge rates than conventional seeding and erosion control BMPs.

Compost vs. Mulch

Pollutant loading is directly proportionate to the volume of runoff generated from a site. This conclusion is supported by research conducted at the University of Georgia, which showed that hydromulch released 2.5 times more total nitrogen, 8 times more nitrate-nitrogen, 8 times more total phosphorous, and 9 times more soluble phosphorous in runoff relative to compost blankets used for erosion control vegetation establishment (Faucette 2008). Another study conducted by Auburn University and the University of Georgia showed that straw mulch with seed and fertilizer released 13 times more total nitrogen and 33 times more soluble phosphorous in runoff relative to compost blankets used for slope stabilization (Faucette 2008). A Texas A&M University study showed that compost erosion control blankets reduced total nitrogen by 88 percent, nitrate-nitrogen by 45 percent, total phosphorous by 87 percent, and soluble phosphorous by 87 percent relative to seed plus fertilizer. An Iowa State study found the compost erosion control blankets used on highway slopes reduced total nitrogen, phosphorous, and soluble phosphorous by 99 percent when compared with seed and topsoil applications (Faucette 2008).

The form of nutrients found in runoff (inorganic or organic) can affect their mobility potential during a storm; however, once the nutrients enter a receiving water body the form is even more critical. Inorganic nutrients are generally soluble in water and readily available for plant uptake, whereas organic nutrient forms typically are not. This rapid uptake can result in rapid growth response, algae blooms, and, ultimately eutrophication in a water body (Faucett 2008).

5.3.2 Comparison of Differing Compost Applications

A study evaluating the sediment nutrient runoff for a series of compost applications was performed by the University of California, Davis and the California Department of Conservation in 2004. These applications included mature and immature compost applied directly to the ground surface or through incorporation. To test the impact of infiltration, the compost blankets were applied to tilled and untilled surfaces. It was found that the highest nitrate losses resulted from compost applications to plots with reduced infiltration due to either lack of tillage or no compost incorporation. The study found that ammonium losses were highest from plots with compost blankets applied over soil with lack of tillage or without compost incorporated into the soil (leading to reduced infiltration). It was also found that immature compost had about 20 percent of the ammonium loss as the mature compost. Ammonium and phosphorous losses were reduced with the presence of grass cover or improved infiltration. The overall conclusion of the study was that the three treatments with the lowest sediment or nutrient losses were the treatments that had grass growth or enhanced infiltration (compost mulch over compost incorporated into the soil). The poorest performing treatments (greatest losses of sediment and nutrients) were those treatments that had a missing treatment component, such as no tillage or no mulch cover, or tillage without compost incorporation, leading to reduced infiltration (Claassen and Carey 2004).

5.3.3 Comparison of Differing Compost Feedstocks

Poultry Litter, Biosolid-Treated, Municipal, and Yard Wastes

The type of compost utilized in erosion control applications has been found to greatly affect nutrient leaching potential (Claassen and Curtis n.d.). A study performed in 2005 presented the cumulative losses in total nitrogen and phosphorous among four compost types added to unvegetated test plots (aged poultry litter, biosolid-treated, municipal, and yard wastes). The study found that total nitrogen losses were highest for the biosolid-based compost and lowest for the yard waste-based compost (61 kilograms per hectare [kg ha^{-1}] and 6.8 kg ha^{-1}, respectively). It found that total phosphorous losses were highest for the biosolid-based compost as well and lowest for the municipal waste-based compost (3.4 kg ha^{-1} and 0.75 kg ha^{-1}, respectively). The study concluded that these differences likely resulted from differences in compost curing levels and organic versus inorganic nitrogen content (Faucette et al. 2005).

Yard Waste Co-Compost

A similar study looking at yard waste compost, yard waste compost mixed with a biosolid sludge, and yard waste compost mixed with bio-industrial sludge found that the soluble concentrations of phosphorous, potassium, and zinc were significantly ($p < 0.05$) greater in runoff from one or more of the composts than from the control plots. The nitrogen concentration, as well as nine other metal concentrations, was below detection. However, the study also found that the control plots lost more nutrients in terms of total mass than the compost treated plots. The study concluded that this was likely because the control plots resulted in much greater volumes of runoff than the compost plots (Claassen and Curtis n.d.).

Green Waste and Biosolid/Green Waste Co-compost

In 2004, a study was conducted by the University of California, Davis and the California Department of Conservation to evaluate the effectiveness of green waste and a co-compost of biosolids and green waste as a soil amendment. Although the study did not monitor the transfer of nitrogen from compost to runoff, it did evaluate the nitrogen release rates from compost for plant uptake. The study concludes that nitrogen release rates varied widely between feedstock materials during the initial portions of the study, with co-composts having much greater release rates than the yard waste composts. Steady, long-term nitrogen releases were observed from composts throughout the second half of the study and were expected to continue on. In the study, composts were shown to provide a suitable replacement source of slowly available nitrogen for plant establishment on drastically disturbed, low-nutrient soils (Claassen and Carey 2004).

Cow Manure Feedstock

In addition to the studies analyzed, a compost feedstock (prior to composting process) analysis report showed sodium levels and pH to be highest in cow manure feedstock when compared with other feedstocks such as onion waste, cow bedding, straw, and grass straw (Midwest Bio-Systems 2007).

5.3.4 Compost as a Pollutant Filter

Compost has proven effective at filtering stormwater pollutants originating from construction sites. Both freestanding berms made of compost and compost socks have surpassed the traditional practices of silt fence and hay bales at reducing the pollutant loads of construction stormwater. Unlike the traditional practices, which work primarily as temporary stormwater detention devices allowing solids to settle out of the water, the berms and socks act as both detention devices and as true filters, removing not only the settleable solids but a significant percent of suspended solids as well as nutrients and hydrocarbons (USCC 2008b).

In a study conducted on compost as filter media, the mean total solids removal was 92 percent, mean suspended solids removal was 30 percent, mean turbidity reduction was 24 percent, and mean motor oil removal rate was 89 percent (Faucette et al. 2006). Moreover, the researchers found that by adding polymers to the filter media, removal efficiencies could be improved, sometimes dramatically. For example, turbidity reduction was increased from 21 percent to more than 77 percent and soluble phosphorous removal increased from 6 percent to 93 percent (USCC 2008a).

6. Findings

Based on evaluation of existing information and studies conducted on the use of compost as it relates to water quality, the following general trends were observed and conclusions were made:

- Regardless of application type (compost, fertilizer, etc.) and as part of RWQCB NPDES compliance requirements, a discharger is responsible for managing storm water runoff from a site and addressing water quality impacts
- Phosphorous concentration in runoff from sites with compost application tends to be higher initially as compared to influent concentration. However, when compared to traditional erosion control methods, compost resulted in significant total reductions in soluble phosphorous in runoff.
- Nitrogen release rates vary depending on the feedstock of the compost.
- Nitrogen and phosphorous were shown to be lower in discharges from sites treated with compost than sites treated with traditional BMPs (i.e., blankets).
- Nutrient concentrations tend to be higher in biosolid-based composts.
- Nutrient concentrations in runoff tend to be lower than those in runoff from treatments with fertilizer.
- Nutrient losses can be most effectively reduced through the use of compost and improved infiltration (e.g., via tillage or compost incorporation).
- Compost, when used as a BMP for filtering runoff such as in a filter sock, berm, or vegetated strip, can reduce nutrient, metal, hydrocarbon, and suspended solid total loads in construction and highway runoff.
- Compost amended soils can reduce the bioavailability of metals when compared to soils without compost.
- Metals concentrations in compost materials can be higher when compared to topsoil but the use of compost can produce significantly lower total masses in runoff of all soluble and adsorbed forms of metals when compared to non-compost test plots.
- The STA Program was established to provide a method for monitoring compost constituents and promote compost quality.
- The composting process destroys pathogens.
- Infiltration is a key component in nutrient and sediment reduction in stormwater runoff.

- Amending soil with compost increases soil porosity and moisture infiltration leading to increased water holding capacity and runoff reduction.
- Caltrans has specifications for compost incorporation, blankets, and socks.
- Referred to as the "First Flush Phenomenon", the initial runoff will have a higher pollutant concentration than runoff at later phases of a storm event.
- Compost use can increase the water holding capacity of soil, thereby reducing runoff and total pollutant load.

In general, existing information and studies evaluated suggest that there can be significant water quality benefits with the use of compost, particularly when used in place of other conventional methods.

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