Compost Demonstration Project, Placer County:

Use of Compost and Co-Compost as a Primary Erosion Control Material

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Table of Contents

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Executive Summary

Yard trimmings and other green materials currently account for over 30 percent of the volume entering California landfills annually. California statute requires landfill volumes to be reduced by 50 percent by the year 2000. In an attempt to meet these requirements, the California Department of Transportation (Caltrans) entered into an agreement with the University of California, Davis (UC Davis) to evaluate the potential for use of green materials composts (GMC) and co-composted materials (CCM; a mixture of green materials and municipal biosolids) for use as primary erosion control amendments for revegetation of Caltrans roadsides.

The research presented here is the initial part of a multi-year project designed to (1) characterize current GMC and CCM products in California to provide information to Caltrans staff for developing specifications for compost use during revegetation, (2) evaluate the performance of surface applications of GMC for primary erosion control in a controlled rainfall facility, (3) evaluate the effect of plant available nutrients provided by GMC and CCM materials for long-term support of vegetative communities, and (4) develop field plots demonstrating the use of composted materials in locations in northern and southern California. The information contained in this report summarizes part of the first objective involving characterization of composted products from private and municipal producers in California during winter 1998-99, as well as describing one of the compost demonstration plots in the Lake Tahoe Basin. Results from remaining objectives will be made available as the project progresses to completion, scheduled for 2001.

Introduction

Compost Definitions

Compost consists of the relatively stable decomposed organic materials resulting from the accelerated biological degradation of organic material under controlled, aerobic conditions (Storey, 1995, Epstein, 1997). Another definition is "the disinfected and stabilized product of the decomposition process that is used or sold for use as a soil amendment, artificial topsoil, growing medium amendment or other similar uses" (Texas Senate Bill 1340; Storey, 1995). This decomposition process converts potentially toxic or putrescible organic matter into a stabilized state that can improve soil for plant growth.

Composting organics has other beneficial effects, including diverting landfill wastes to alternative uses, removal of pathogen inocula or weed seeds and decomposition of petroleum, herbicide or pesticide residues. These aspects, though important, will not be considered here, nor will the potential for metal transport or accumulation by organic molecules. The focus of the project described here is to evaluate the benefits of using GMC as a mechanical aid for primary erosion control and as a nutrient source for sustainable revegetation of degraded soils.

Potential for Use of Compost as a Primary Erosion Control Material

A primary limiting factor in the revegetation of degraded soils is the loss of the erosion-resistant plant litter layer and soil nutrients during and after disturbance of the soil resource (Bradshaw and Chadwick, 1980). Loss of plant litter and mulch material results from erosion or physical removal during construction. The first soil horizons to be removed are typically deposited at the bottom during fill slope construction. The remaining soil surface is exposed and the nutrients in the previous topsoil horizons are buried beyond the reach of plant roots.

Revegetation of drastically disturbed sites often requires protection of the bare soil surface from erosion. The bare soil particles are vulnerable to raindrop impact, which detaches or close-packs the disaggregated fines. When the surface of the soil seals and becomes resistant to percolation of precipitation, overland flow is increased, resulting in sheet and rill erosion. Composts are shown to reduce these types of erosion, as noted in the literature review below.

Loss of topsoil during disturbance also reduces the ability of the vegetative community to regrow because the soil's nutrient reserves are depleted. Inadequate pools of plant-available nitrogen (N) can restrict growth on the site for extended periods of time because N is needed in relatively large amounts for regeneration of the shoots, roots, litter layers, and for microbial biomass. Because soluble fertilizer N is easily depleted from the soil by leaching or plant uptake, the regeneration of the plant community is expected to be improved by the application of larger, stabilized pools of N that mimic the organic matter lost during topsoil removal. Recent work in the Tahoe Basin suggests that these long-term, slowly available pools are better correlated with the soil's ability to support plant growth, than are soluble (KCl-extractable) N levels (Claassen and Hogan, 1998).

While many organic or chemically based soil amendments can provide N for early phases of plant establishment, few provide N for a long-term, multi-year period of community development. GMC, on the other hand, may provide this type of N release because the composting process converts readily degradable organic materials into stabilized, partially humified materials (Epstein, 1997). Before evaluating the nutrient contents of GMC products in California, the practices and results from projects in other states will be reviewed.

Review of Existing Projects in States Other Than California

Texas Transportation Institute

The Texas Transportation Institute, Hydraulics and Erosion Control Field Laboratory, affiliated with the Texas A&M University system, has developed a testing facility with large, life-sized experimental slopes for uniform testing of erosion control materials. A study on compost application (Storey, 1995) tested three materials on 1:3 slopes with both clay and sandy loam textured soils. Plot size was 6.1 m wide by 21.35 m downslope (1:3 slope plots). These materials included co-compost (mixed yard trimmings and municipal sewage sludge), shredded wood with polyacrylide tackifier (6.75 kg/ha), and shredded wood with a hydrophilic colloid tackifier (56 kg/ha).

Treatments were amended with organic materials to a depth of 76 to 101 mm (3 to 4 in) over the clay or sandy loam soil. Soils were seeded with a standard warm season revegetation grass mix for the central Texas area. Vegetation establishment criteria were a minimum coverage of 80 percent for the clay soils and 70 percent for the sandy loam soils within 6 months of seeding. Rain simulations tested for sediment loss on the plots, using 1-, 2-, and 5-year simulated storm events. The erosion control objectives are that the treatment should protect the seed bed from a short-duration, 1-year return frequency event (99 percent probability of occurrence within a given year) within the first month after installation, from a 2-year return frequency event (50 percent probability) within the first 3 months following installation, and from a 5-year return frequency event (20 percent probability) within the first 6 months of installation. Rainfall simulations were designed to model events within the Houston/Dallas/Austin region. To be included in the Texas Department of Transportation-approved Material List for Standard Specification Item 169 (Soil Retention Blanket), the sediment loss had to be 0.34 kg/10 m^2 or less from the clay soils and 12.21 kg/10 m^2 or less from the sandy loam soils.

Sediment loss from the compost-amended plots during simulated rainfall tests was right at 0.34 kg/10 m^2 from the clay plots and was 3.88 kg/10 m^2 for the sandy loam plots. Vegetation cover was 99 percent on the clay and 92 percent on the sandy loam. The two tackified wood chip treatments produced 0.15 and 0.30 kg/10 m^2 sediment loss on the clay soil and 11.27 and 10.97 kg/10 m^2 sediment loss on the sandy loam. Vegetation establishment was around 50 percent for several of the tackified wood chip treatments, disallowing them from approval under Texas Department of Transportation standards. The fact that much of the vegetative cover established in the compost treatment came from weed seed, not the desired seed mix, points out the need for quality control in compost products. Costs for the compost were below the average cost of synthetic or organic blankets tested by the facility.

Portland Metro, Portland Oregon

The goal of a Portland Metro project was to demonstrate that yard trimmings compost can be used effectively to control nonpoint-source pollution (Ettlin and Stewart, 1993; Metro, 1994). The project used both "coarse" compost materials (containing chunks of wood and branches up to 152 mm [6 in] in length) and "medium" compost materials, the fraction remaining following screening of the coarse compost through a 16-mm (5/8-in) trommel. Leaf compost was collected from residential streets in the city of Portland.

Thirteen test plots measuring 2.74 x 9.75 m (9 x 32 ft) were constructed on slopes of 34 and 42 percent. Surface runoff was collected in plastic sheeting at the base of the slope. A 3-in mulch layer was applied either as a uniform covering or as a barrier at the base of the plot. Two conventional methods, sediment fences, and wood fiber hydromulch with tackifier treatments were also tested and compared to untreated controls. During and after three storm events in March 1993, 364 samples were collected and tested for suspended solids, settleable solids, turbidity, total solids, metals, nitrate N, total N, and chemical oxygen demand. Suspended solids were lower on the compost treatments than with the sediment fences and similar to the wood fiber hydromulch. Composts also adsorbed metals, reducing metal runoff. The need for high-quality, mature compost was noted.

Subsequent to this study, field plots were constructed in the Portland area utilizing compost as erosion control material to demonstrate use and to increase the market demand for yard trimmings compost materials. Three field sites were established on roadside, housing development, and mobile home park projects. All compost materials were applied to a depth of 76 to 102 mm (3 to 4 in). Materials were brought to the top of the slope by tractor bucket or backhoe. Materials were then spread by hand. The first site (Springwood Drive, Beaverton) had a 14-degree slope at the bottom and a 7.6 m (25-ft) slope length, and the slope drains into an existing wetland. At the second site (Marylhurst, Lake Oswego), slopes ranged from 0 to 30 degrees. The third site (McLoughlin Boulevard, Portland) contained two areas with slope angles of 35 degrees and slope lengths of 3 to 18.3 m (10 to 60 ft). A third area had a slope angle of 15 degrees and a slope length of 4.6 m (15 ft), and a fourth area had a 1- to 5-degree slope and a slope length of 48.8 m (160 ft).

Results from the three demonstration projects suggest the following beneficial uses from compost application. A thick compost layer can provide a surface covering for foot or vehicle traffic onto soils that are otherwise too muddy and wet to support traffic. A compost layer at the exit of a site will reduce mud tracking onto local streets and into storm drains. A 76-mm (3-in) layer of compost was found to be effective. One demonstration site coordinator suggested using a specification of a “minimum” of 3 inches. Compost screened to 38 mm (1½ in) or less is recommended for erosion control on steeper slopes. Slopes of up to 35 degrees were effectively treated. The compost layer should be extended over the top of the slope for 0.6 to 1 m (2 to 3 ft) at a 300- to 450-mm (12- to 18-in) depth to diffuse ponded water entering the top of the slope. Compost that has been screened to 19 mm (¾ in) or less is recommended for slopes that are to be landscaped. A moisture content of less than 25 percent makes application most efficient and enables the compost layer to readily adsorb larger amounts of rainfall immediately after application. Mature compost will function to release nutrients into the soil more readily than immature compost. Contaminants (plastic, glass, undecomposed plant material) detract from the aesthetic benefits of compost amendment. As a result of the study and field plots, members of several local governments incorporated the use of compost into their specifications.

Other Miscellaneous Studies Outside of California

Various studies were located in the literature search that provide smaller, though relevant, findings regarding the development and use of GMC. They are listed in a nonprioritized sequence below.

Leaf composting facilities exist in 140 of the 351 municipalities in Massachusetts (Fulford et al., 1993). Grass clippings have high nutrient contents and therefore are potentially putrescible. Careful management is required to maintain aerobic conditions and to control nutrients and odor moving off site. New Alchemy Institute, BioThermal Associates, and Woods End Research Laboratory cooperated on a study designed to determine the impacts on air, water, and soil from composting grass clippings in windrows, including the fate of pesticide residues. Ratios of greater than 1 part grass to 3 parts tree leaves in the compost mix resulted in excess nitrate production. Some nitrate, chloride, and potassium leached beneath the piles, but little of the total N left the piles. Pesticide residues were very low.

In the late 1980's, Florida Department of Transportation maintenance crews typically chipped vegetation trimmings and spread them beneath plantings (Henry and Bush, 1996). After a large pile caught fire and exposed some barrels stored under the chipped material, the informal process of composting on site was shut down. An official composting and recycling program was restarted in 1992. As part of the development program, the University of Florida Horticultural Sciences Department conducted a study on proper use of composted waste materials for roadside applications. Current turfgrass applications of about 4000 tons of fertilizer per year are proposed to be replaced by 20,000 to 40,000 tons of compost per year, pending study by the University of Florida.

Although composts have been evaluated for their ability to improve plant growth for many years, most studies have involved municipal solid waste composts (MSWC, or mixed municipal garbage) or sewage sludge composts. Further, many of these tests produce little detailed data on characterization or use (Henry et al., 1991). A University of Washington study (Henry and Harrison, 1992) mainly reports analyses of totals of metal elements, with little bioavailability data.

Humic acids from green materials composts were compared with leonardite humic acids for their effect on aggregation of a silty-clay Fluvisol (Canarutto et al., 1996). Higher rates of leonardite humic acids (0.2 to 0.8 percent humic acid addition) decreased aggregates in the microaggregate classes ranging from 38 to 250 micrometers in diameter, while no change was generated by humic acids from GMC. Humic acids from GMC materials decreased the size of the clod (thick, hard-setting crust) as the soil dried.

MSWC additions to soils were associated with shifts in the bacterial populations, probably as a result of increased carbon substrates (Press et al., 1996). Newsprint plus poultry litter caused shifts to Gram negative bacteria (common root colonizers and biocontrol organisms) compared to newsprint plus ammonium nitrate. Increases in bacterial populations that have beneficial effects on plant growth may indicate changes in soil quality. Materials that contained initial carbon to nitrogen (C:N) ratios of 20:1 and were composted for 9 weeks increased fungal populations compared to materials with C:N ratios of 60:1. Straight newsprint applications to surfaces increased cotton plant rot disease and soreshin disease, both caused by fungal pathogens. Application of material with C:N ratios of < 30:1 increased bacterial populations.

Quality of compost materials is closely linked to process (Barnes and Heimlich, 1992). The best way to bulk up high nutrient grass clippings (when compared to straw and wood chips) was found to be with tree leaves. Odor problems developed when pile temperatures exceeded 65 °C (150 °F).

Grass materials were composted in a trapezoidal windrow system about 3 m high by 53 m wide (10 ft by 175 ft) (Logsdon, 1993). Grass materials are bulked with tree leaves or wood chips. Odor problems were controlled when 5 parts leaves or chips were used to 1 part grass material. Plastic bags compound the problem of odor production. Because of recurring odor problems, the Hunting Woods, Michigan, facility refuses to collect grass clippings.

In Jacksonville, Florida, high-C-content materials (tree leaves) are placed in alternate windrows during February and then the inter-row spaces are filled with high-N-content grass clippings in the spring and summer (Kelly, 1993). The two piles are then blended together and turned five times in a 90-day composting process.

A dune stabilization project in Ft. Lauderdale, Florida, utilized 76 mm (3 in) of compost with grass plugs (Sea oats) planted on 46 cm centers (18 in) (Hamilton et al., 1993). Drip irrigation pipe was installed, followed by another 76 mm (3 in) of mulch material. With these intensive treatments, plant growth within a single 5-month season was equivalent to that of a 5-year growth without treatment.

In a study of yard trimmings compost usage in Minnesota, macronutrients and micronutrients were tested, but only soluble (extractable) N pools were measured (Gurkewitz, 1989). With a C:N ratio of approximately 49, the material is not expected to release additional N until it is further stabilized. Metals were below Minnesota's regulatory limits.

Setting testable standards for "high quality" is difficult. Hegberg et al. (1991) measured a wide range of metals, all of which were beneath the Minnesota standards. Extractable and total N levels were measured, but mineralizable N pools were not.

Selected Projects in California

Caltrans Compost and Co-Compost Study

Caltrans developed a project entitled "Evaluation of compost and co-compost materials for highway construction" (Sollenberger, 1987) that tested sewage sludge composts and sludge/municipal refuse co-composts. The materials were found to be usable as fertilizers, soil amendments, and erosion control materials only if the quality was good (permissable contents of heavy metals, toxic organics, pathogenic organisms, and low content of glass, plastic and metal). Because the focus of the Sollenberger (1987) study was on sludge and municipal refuse composts, the data are of little use regarding the current erosion control project, except to illustrate the relatively clean, low-contaminant content of GMC compared to composted municipal solid waste materials.

Caltrans Green Material Mulch Demonstration

A second Caltrans-funded project addressed the use of green material for surface application on roadways (Pollock and Moreno, 1993). This project was developed in cooperation with the California Integrated Waste Management Board for the purpose of determining whether green materials, including residential yard clippings, and similar clean organic refuse could be used for weed control, soil improvement, conservation of irrigation water, plant fertilization, and aesthetic improvement of landscape sites. The materials utilized were variously called "mulch" and "composted mulch" but were, in fact, not compost. Composted materials are those that have undergone thermophilic decomposition and organic matter stabilization. The materials used in this study contained particle sizes such that 82 to 99 percent (Caltrans District 3) or 62 to 99 percent (District 11) passed through a 9.5-mm screen. The District 3 materials were characterized as having a greater volume of 6.3 mm (1/4-in) particles, with smaller proportions of larger and smaller particles. The District 11 materials contained either fine-sized particles plus wood chips and cuttings less than 150 mm (6 in) in length (Miramar source materials), or particles from 150 to 450 mm (6 to 18 in) in length (Otay Landfill source materials).

Results from both districts indicate that plant growth was generally improved as a result of increased moisture retention, more moderate soil temperatures, and an enhanced habitat with greater fungal, insect, and vertebrate animal activity. The mulch materials were observed and measured to be very low in nutrient content. Quality control criteria were difficult to establish, but will be critical for widespread use of mulch materials. The reports advised that composted mulch materials should not be applied within the dripline of trees because of the observation of increased fungal rot of existing trees. Equal mixes of green materials and wood chips appear to benefit plant growth, and mulch depths of not less than 300 mm (12 in) are recommended. In conclusion, this study documented benefits of mulch materials for improved vegetative growth, but did not evaluate composted green materials. Even where the mulch materials were partially composted, their use and application was as a surface mulch rather than as an incorporated soil amendment.

Santa Cruz County Projects

Benefits and concerns regarding agricultural uses of uncomposted green materials are reviewed well in the final report for the Green Waste Demonstration Program for Santa Cruz County (Buchanan and Grobe, 1997). In this program, a number of agricultural uses for processed green materials (chipped, but not already composted) were identified and evaluated. These uses included on-farm composting, permanent mulching of row crops and farm roads, applications related to flower production in fields and greenhouses, and direct soil incorporation. This information represents an alternative use of green materials and can provide insight on some of the benefits and problems associated with the use of GMC in field situations.

End uses of the uncomposted green materials varied greatly. A farming operation with a loamy sand soil used a 76- to 102-mm (3- to 4-in) layer as a roadway mulch to reduce dust during summer and erosion during the rainy season. A coarse grind and a high C:N ratio were an advantage in reducing decomposition rates. Greenhouse applications of 51 to 76 mm (2 to 3 in) depth required adequate ventilation to reduce buildup of ammonia gas from the green material. One greenhouse mulch material was too dry at application, generating respiratory complaints. One case of contact with poison oak was reported. A field amended with 11.2 to 13.4 megagrams/ha (5 to 6 tons/ac) performed well when plants received preplant N application. Green material was generally found to be equivalent to redwood sawdust or rice hull for adding organic matter to soils. Another field application with 56 megagrams/ha (25 tons/ac) of green material incorporated into the soil reduced growth on raspberries due to N deficiency. Even with supplemental N, the plants performed poorly. Non-screened material greater than 16 mm (5/8 in) was difficult to apply mechanically.

Consistent production quality and characterization are recognized as being key to increasing the use of these heterogeneous organic materials. Many of the characteristics varied greatly as a result of storage time and conditions (temperature, aeration, moisture and leaching). Nitrogen content, for example, varied by 385 percent. Nitrogen measured from selected samples taken immediately after grinding was 1.7 percent, but decreased rapidly with time, from 1.7 percent to 0.49 percent after 3 weeks. Other macronutrients (K, Ca, Mg, SO_4) varied by 333, 460, 330, and 320 percent. Product variability could be reduced by segregation of loads with higher proportions of tree leaves, grass or other succulent materials for use in compost production, while loads with more woody material could be separated for use as soil surface mulch or topdressing. Analysis of metals in these green waste materials shows little evidence for excessive contamination for metals under California Title 14 and U.S. Environmental Protection Agency (EPA) 503 regulations. Some batches of ground and recycled wood waste may, however, have lead and arsenic contamination resulting from contamination from paints and wood preservatives.

Only one complaint was made regarding contamination from inerts (plastic, rubber, aluminum) during the demonstration program. The presence of viable weed seeds in uncomposted green materials was common. Source separation of leafy materials and fines (dirt and ground up plant material) from compost feedstock materials will reduce spread of weed seeds. Coarse woody feedstocks can be directed to uses involving uncomposted materials. To limit the spread of pitch canker, an endemic disease of Monterey Pine in the coastal area around Santa Cruz, it is recommended that uncomposted materials not be transported to other forested areas in the state.

Reasons given by growers for not wanting to use uncomposted green materials include lack of equipment and space, fear of disease and weed seed problems, and familiarity with use of manures as soil amendments rather than green materials.

An earlier report (Grobe and Buchanan, 1993) reported that typical successful application rates for soil amendment range from 11.2 to 22.4 megagrams/ha (5 to 10 tons/ac). User concerns involve (in decreasing order of importance) contaminants, price, pathogens, salt, and nutrient content. Composts improve microbial activity that can act to reduce root pathogens and improve nitrogen use efficiency.

Caltrans Compost Demonstration at Brockway Summit, Placer County (in progress)

In the fall of 1998 a compost demonstration was constructed at Brockway Summit on State Highway 267 in Placer County, at the north end of the Lake Tahoe Basin. This project involved a long series of southwest-facing road cuts totaling 3.6 ha (9 ac), with 2:1 (horizontal:vertical) slope angles. The parent materials are volcanic mudflows that were cut to 5 to 8 m below the previous soil surface.

The existing erosion control specification for the site was modified to create three additional treatments designed to contrast the performance of various slope amendments. Each of four treatments—specified, zero control, compost, and compost plus specified—was repeated on three separate slopes (Table 1). The slope amendments were stable through the winter of 1998–1999 with only small areas of slippage. Plant growth and soil nutrient content will be monitored for several years after application.

Table 1. Treatments applied to the Brockway Summit Compost Demonstration Project in Placer County, State Highway 267.

Treatment Code	Application Number	Description
SPECIFIED	Application 1	600 kg/ha compost, 800 kg/ha organic soil amendment (Biosol), 150 kg/ha fiber, and seed materials
	Application 2	Pine needles to a depth of 25 mm
	Application 3	600 kg/ha compost, 400 kg/ha organic soil amendment (Biosol), 150 kg/ha fiber, and 140 kg/ha tackifier
ZERO CONTROL (omit compost and organic soil amendment)	Application 1	150 kg/ha fiber, and seed materials
	Application 2	Pine needles to a depth of 25 mm
	Application 3	150 kg/ha fiber and 140 kg/ha tackifier
COMPOST (replace compost and organic soil amendment with equivalent N amount from GMC)	Application 1	150 kg/ha fiber and seed materials
	Application 2	Pine needles to a depth of 25 mm
	Application 3	150 kg/ha fiber and 140 kg/ha tackifier
	Application 4	10 cu yd (approximately 9000 kg/ha GMC)
COMPOST + SPECIFIED (amend with both GMC and specified compost, organic soil amendment)	Application 1	600 kg/ha compost, 800 kg/ha organic soil amendment (Biosol), 150 kg/ha fiber, and seed materials
	Application 2	Pine needles to a depth of 25 mm
	Application 3	600 kg/ha compost, 400 kg/ha organic soil amendment (Biosol), 150 kg/ha fiber, and 140 kg/ha tackifier
	Application 4	10 cu yd (approximately 9000 kg/ha GMC)

Survey of Compost Products in California

Layout of Study

To evaluate the nutrient levels in current GMC and CCM products in California, 22 composted or co-composted materials and 1 uncomposted material were sampled in December 1998 and January 1999. The purpose of the sampling survey was not to check products against an existing criteria for quality, but to evaluate the range of material that would be available to Caltrans at a given point in time, should a revegetation project require GMC for use as a primary erosion control material and soil amendment.

Sampling and Analysis Methods

A standard sampling protocol was used for collection of material from producer sites. The "typical" material from each producer that would be shipped out to a large project was selected and then sampled from four evenly spaced points around the pile. A 4-liter (1.057-gal) volume was collected at each sampling point. Samples were collected at 1-m depths into the pile at a height of about 1–3 m from the base. Temperatures were measured at each sampling point to characterize whether the pile was still respiring or had cooled off. Surface samples were not collected because this zone made up relatively little of the volume of the bulk of the pile.

One composite sample was created for each source material and was submitted for commercial compost analysis (A91 compost evaluation, Soil and Plant Laboratory, Santa Clara, California). These analyses were averaged by compost source material (green materials compost, biosolids/green material co-compost, agricultural byproduct composts, or other sources).

Results

Fourteen of the samples listed in Table 2 were green materials composts (GMC). Four samples were biosolids/green material co-composts (CCM). Three were agricultural byproduct composts (AGC). Two materials were listed as "Other": the Brea material was an uncomposted green material, and the Upper Valley material was a grape pomace/prunings compost. The 21 remaining compost materials were averaged by source material.

General Chemical and Physical Characteristics

GMC materials had much lower salinity than either CCM or AGC (Table 3). Much of the nearly 32 dS/m salinity measured in AGC came from KCl or NaCl. The salinity of the CCM was about half (16 dS/m) of the AGC. GMC had the lowest average salinity at 9.4 dS/m. The pH of the AGC was also the highest at 8.7. The pH of GMC averaged 7.6 while the CCM was slightly under 7.0.

The AGC was somewhat finer in particle size than either the GMC or CCM, having virtually all the material less than 1/2 in. Two-thirds of the AGC also passed the 1-mm sieve, while approximately half of the GMC and approximately a third of the CCM was that fine. Bulk density of the dry material was similar (726 to 840 lb/cu yd).

Table 2. List of compost and co-compost producers, in alphabetical order, with compost source material listed at right. See Appendix C for key to acronyms and abbreviations.

Producer	Source Material
1. Agri-Fuels, Inc., 24478 Road 140, Tulare, CA 93274	GMC
2. BFI Organics, Newby Island Composting Facility, 1601 Dixon Landing Rd., Milpitas, CA 95035	GMC
3. Brea Green Recycling, 1983 Valencia Ave., Brea, CA 92621	Uncomposted green materials
4. Cold Canyon Landfill, 2268 Carpenter Canyon Rd., San Luis Obispo, CA 93401	GMC
5. Community Recycling and Resource Recovery, 1261 N. Wheeler Ridge Rd., Lamont, CA 93241	CCM
6. Contra Costa Landscaping, P.O. Box 2069, Martinez, CA 94553	GMC
7. EKO Systems, Inc., 8100-100 Chino/Corona Rd., Corona, CA 91720	AGC
8. Foster Farms, 12997 West Highway 140, Livingston, CA 95334	AGC
9. Gilton Resource Recovery Transfer Station, 880 South McClure Rd., Modesto, CA 95354	GMC
10. Greenway Compost, 3210 Oceanside Blvd., Oceanside, CA 93056 (El Corazone)	GMC
11. Mt. Vernon Recycling Facility, City of Bakersfield, 2601 S. Mt. Vernon Ave., Bakersfield, CA 93309	GMC
12. New Era Farm Service, 23004 Rd 140, Tulare, CA 93274	AGC
13. North Valley Organic Recycling, P.O. Box 1159, Chico, CA 95927	GMC
14. Recyc, Inc., 114 Business Center Dr., Corona, CA 91720	GMC
15. Redding, City of, Transfer/Recycling Facility, 2255 Abernathy Ln., Redding, CA 96003	GMC
16. Sacramento, City of, Solid Waste Division, 20 28th St., Sacramento, CA 95814	GMC
17. San Diego, City of, Environ. Serv. Dept., 9601 Ridgehaven Court, Ste. 320, San Diego, CA 92123	GMC
18. San Joaquin Compost, 12321 Halloway Rd., Lost Hills, CA, 93249	CCM
19. Santa Rosa, City of, Laguna Treatment Plant, 4300 Llano Rd., Santa Rosa, CA 95407	CCM
20. Sonoma Compost, 550 Meacham Rd., Petaluma, CA 94952	GMC
21. Turlock, City of, 901 S. Walnut Rd., Turlock, CA 95380-5123	CCM
22. Upper Valley Disposal and Recycling, P.O. Box 382, 1285 Whitehall Ln., St. Helena, CA 94574	Grape pomace composts
23. Zanker Road Resource Mgmt., 705 Los Esteros Rd., San Jose, CA 95134	GMC

Table 3. Summary table of characteristics by source material from 21 compost producers, excluding source materials that are not GMC, CCM, or AGC. See Appendix C for key to acronyms and abbreviations. Analyses from Soil and Plant Laboratory, Inc., Santa Clara, CA (A91 Compost Evaluation).

Total Nutrient Contents and Other Characteristics

		Total nutrient contents												Other characteristics			
		% N	% P	% K	% Ca	% Mg	% Na	% S	ppm Cu	ppm Zn	ppm Mn	ppm Fe	ppm B	TEC	half sat%	pH	ECe
All materials																	
	X	1.4	0.6	0.9	2.3	0.6	0.2	49.9	123.6	263.8	356.3	15363	58.4	513.3	60.8	7.7	14.0
	s	0.4	0.6	0.6	0.7	0.2	0.1	50.5	89.0	168.4	136.3	7261	19.3	156.8	25.2	0.6	9.2
	CV	30.5	97.4	64.8	30.5	34.5	61.8	101.2	72.1	63.8	38.3	47	33.0	30.5	41.5	8.1	65.6
Green material composts (GMC)																	
	X	1.2	0.3	0.8	2.0	0.6	0.2	20.5	75.4	182.5	343.9	14874	58.4	485.6	64.1	7.7	9.4
	s	0.2	0.0	0.3	0.5	0.2	0.1	21.7	31.0	50.5	125.7	7351	13.4	88.3	22.0	0.3	4.4
	CV	17.8	18.2	30.1	23.3	29.0	50.9	106.1	41.2	27.7	36.6	49	23.0	18.2	34.3	3.5	46.4
Co-composted biosolids/green materials (CCM)																	
	X	1.9	1.5	0.4	2.6	0.5	0.2	96.4	261.5	536.8	283.8	18785	48.0	691.5	66.0	7.0	16.8
	s	0.6	0.5	0.1	0.6	0.1	0.0	33.4	43.6	190.5	92.5	8939	19.0	241.4	39.2	0.7	5.8
	CV	29.4	29.9	32.8	21.9	22.9	26.4	34.6	16.7	35.5	32.6	48	39.6	34.9	59.4	10.3	34.4
Agriculture byproducts composts (AGC)																	
	X	1.3	1.2	2.1	3.0	0.9	0.4	125.2	164.7	279.3	511.0	13082	72.3	405.0	38.7	8.7	31.9
	s	0.5	0.6	0.7	1.2	0.3	0.1	43.2	115.4	130.2	150.5	4819	38.8	145.4	7.0	0.4	5.3
	CV	38.7	55.0	33.8	41.0	31.8	32.8	34.5	70.1	46.6	29.4	37	53.6	35.9	18.2	4.7	16.7

Available Nutrient Levels

		NaCl extract					Bicarb extract	DTPA extract				Sat ext			Dil acid % Fe
		ppm NO_3-N	ppm NH_4-N	ppm K	ppm Ca	ppm Mg	ppm PO_4-P	ppm Cu	ppm Zn	ppm Mn	ppm Fe	ppm B	% ECe Na	meq/L Cl	
All materials															
	X	341.6	739.7	6587.0	4533.6	1436.6	493.8	17.0	78.6	72.8	265.6	2.7	29.3	53.4	0.4
	s	413.2	1239.6	2954.9	2366.1	432.0	526.3	23.2	45.0	39.7	203.0	2.3	27.3	44.4	0.4
	CV	121.0	167.6	44.9	52.2	30.1	106.6	136.0	57.2	54.6	76.4	84.2	93.0	83.1	103.4
Green materials composts (GMC)															
	X	199.5	142.4	6752.2	4578.6	1514.9	277.4	6.4	56.1	77.0	234.6	2.0	18.7	43.4	0.2
	s	272.6	176.7	1497.8	1654.0	471.2	108.8	3.8	20.2	37.6	187.4	1.6	15.7	25.5	0.2
	CV	136.6	124.0	22.2	36.1	31.1	39.2	58.8	35.9	48.9	79.9	83.4	83.7	58.7	96.2
Co-composted biosolids/green materials (CCM)															
	X	950.8	3119.8	2898.5	6448.5	1426.5	729.5	36.1	131.5	53.0	361.0	2.3	25.5	27.8	0.9
	s	384.1	816.2	1094.7	3564.6	186.9	686.3	6.8	37.1	46.0	257.1	1.3	12.9	21.7	0.5
	CV	40.4	26.2	37.8	55.3	13.1	94.1	18.9	28.2	86.8	71.2	57.2	50.4	78.0	57.9
Agriculture byproducts composts (AGC)															
	X	192.7	353.3	10734	1770.3	1084.3	1189.3	41.1	112.7	79.3	283.3	6.9	83.8	134.2	0.3
	s	293.9	337.8	4211.1	585.5	375.6	906.6	53.2	68.1	49.2	243.5	1.3	17.9	54.5	0.3
	CV	152.5	95.6	39.2	33.1	34.6	76.2	129.4	60.5	62.0	86.0	19.2	21.4	40.6	100.4

Physical Characteristics

				These analyses on 1/2" minus material													
		% Overs, 1"	% Overs, 1/2"	Bulk density, lb/cu yd	Moisture content, %	Water, lb/cu yd	Dry matter, lb/cu yd	Organic fraction, lb/cu yd	Mineral fraction, lb/cu yd	Organic %	% of material passing screen size listed (mm)						C:N ratio
											9.51 mm	6.35 mm	4.75 mm	2.38 mm	1.00 mm	0.50 mm	
All materials																	
	X	0.0	1.4	1222.8	35.7	424.7	798.8	285.1	513.0	35.7	97.7	92.4	88.0	73.2	48.7	29.8	16.4
	s	0.0	1.3	271.4	11.1	134.2	263.7	54.9	261.7		2.7	6.9	8.9	13.0	13.9	12.6	5.9
	CV		89.6	22.2	31.0	31.6	33.0	19.2	51.0		2.8	7.5	10.1	17.8	28.6	42.2	35.7
Green material composts (GMC)																	
	X	0.0	1.5	1168.6	38.0	442.4	726.4	283.9	442.6	39.1	97.7	91.7	87.3	72.6	49.0	30.3	18.9
	s	0.0	1.3	254.8	9.2	146.3	189.6	21.8	194.6		2.3	6.4	7.7	9.3	10.5	11.2	5.3
	CV		84.7	21.8	24.2	33.1	26.1	7.7	44.0		2.4	7.0	8.9	12.8	21.5	37.0	28.0
Co-composted biosolids/green materials (CCM)																	
	X	0.0	2.0	1295.3	38.0	457.0	840.3	313.5	524.5	37.3	96.3	89.9	83.0	61.7	34.5	19.1	12.5
	s	0.0	1.3	343.8	15.0	87.6	406.1	52.2	378.7		4.3	9.4	11.7	15.3	15.8	13.9	3.6
	CV		65.7	26.5	39.4	19.2	48.3	16.6	72.2		4.5	10.4	14.1	24.8	45.7	73.2	29.1
Agriculture byproducts composts (AGC)																	
	X	0.0	0.2	1378.7	21.9	298.7	1081.7	253.0	826.7	23.4	100.0	98.7	97.7	91.3	65.8	42.1	10.3
	s	0.0	0.4	264.0	2.1	34.0	233.0	140.6	203.2		0.0	1.5	1.8	5.2	1.1	4.0	3.6
	CV		173.2	19.2	9.5	11.4	21.5	55.6	24.6		0.0	1.5	1.9	5.7	1.6	9.5	35.4

Macronutrient Contents

Total nitrogen was highest (1.9 percent) in the biosolids/green material co-composts (CCM) (Table 3). GMC and AGC were similar at 1.2 and 1.3 percent N. The amount of this N that will mineralize (release) and become available for plant uptake depends on the available C. These assays only provided an estimate of the C:N ratio. A ratio less than 20 is generally expected to indicate a material that will mineralize N, although this depends on the quality of the C. The GMC had a C:N ratio of about 19, the CCM of about 12, and the AGC of about 10. Extractable (immediately available, solution N) did not follow this trend. CCM had by far the highest extractable N at over 3100 ppm, followed by AGC at 353 ppm and GMC at 142 ppm. Further work is needed to adequately evaluate the ability of the compost to provide N for plant growth.

The variability of these N assays between producers within each source material group was moderate to high. Typical soil samples may have a coefficient of variation (CV) of about 20 percent. This is approximately the CV value of the total N for the GMC, while the variability of the CCM and AGC materials was much higher. This suggests that GMC samples will be more consistent between producers and can be characterized more reproducibly by specifications. In contrast, the extractable N levels for GMC and AGC had CVs greater than 100 percent, while for CCM the CV was 40 percent for nitrate and 26 percent for ammonium. A higher CV is expected from this soluble, easily changed N pool.

Phosphorus (P) levels were 0.2 percent for GMC, 1.5 percent for CCM, and 1.1 percent for AGC. The high P level is typical for material containing biosolids. GMC had the lowest CV for total P, and would be the best characterized by a specification.

Potassium (K) was moderate (0.8 percent) in GMC and 0.4 percent in the CCM. The AGC had much higher total K (2.1 percent), which contributes partly to the high salt content. Sodium (Na) was also over twice as high in the AGC as in the other two materials.

Sulfur (S) was much lower in GMC (20 meq/l) than CCM (96 meq/l) or AGC (125 meq/l).

Calcium (Ca) was similar in all source materials (2 to 3 percent). Magnesium (Mg) was twice as high in the AGC (0.9 percent) as in the CCM and GMC (0.5 to 0.6 percent).

Total copper (Cu) and zinc (Zn) were much lower than the legal limits cited for these metals in municipal solid waste compost in Minnesota and New York (Hegberg et al., 1991). Within the products sampled from California, total Cu and Zn in GMC were about a third of those in the CCM samples. Bioavailable metals were measured by the DTPA extracts, which generally followed the same trends as the total levels. Similarly, baseline data in the Santa Cruz Green Waste Demonstration Project (Buchanan and Grobe, 1977) showed little evidence for excessive contamination for metals under California Title 14 and US EPA 503 regulations.

In general, the variability of the 21 compost samples was very high when viewed as a whole, but when the samples were separated by source material, the variability was reduced. Based only on the N assay data, specifications for total N in GMC should work reasonably well, although statistical evaluation of the data is still in progress. In contrast, the variability in the extractable N levels was greater than the mean, making this parameter difficult to specify. Typical CVs for other compost characteristics ranged from 40 to 80 percent, making specification of these characteristics difficult as well. Further data analysis will be done, perhaps to evaluate a "minimum content" type of specification rather than an average.

Future Study Directions

Duplicate samples from the field survey will be analyzed at UC Davis for the content and release rate of various N pools contained within the compost. These N pools include short-term or extractable (soluble) N, mineralizable N, which is more gradually available, and total N, which is the sum of all forms. These three tests are existing, standard tests for N availability, but they do not evaluate slow-release N that is needed during the years that the plant community is regenerating. Methods to measure this pool of “slowly available” or "organically stabilized" N are being developed. This N fraction is particularly interesting because it is expected to be more rapidly available than much of the total N pool, but is slower and longer- lasting than the extractable and mineralizable N pools. This assay is intended to allow more effective screening of compost materials for appropriate N composition, N release rate, and maturity. Tests will continue through the summer of 2000.

Conclusions

Field application projects in California and other states suggest that GMC is an excellent amendment material for erosion control and revegetation of degraded soils. Preliminary analysis of compost products from different producers in California suggests great variability, making accurate specification and amendment difficult. Further work is in progress regarding methods for evaluating desired characteristics of compost products and for development of monitoring methods for compost performance in the field. In particular, information is needed on release of plant-available N for plant growth and community development. This parameter is critical, since inadequate N has been observed to reduce plant establishment on harsh sites. The effectiveness of surface application of composted materials in retaining moisture also needs to be documented in field situations.

Bibliography

Barnes, J., and J. Heimlich. 1992. Leaves prove best bulking agent for grass clippings. *BioCycle*. 33(5):38–39.

Buchanan, M., and K. Grobe. 1997. *Green Waste Demonstration Program*. County of Santa Cruz. Public Works Department, Solid Waste Division, 701 Ocean Street, Room 410, Santa Cruz, CA 95060.

Canarutto, S., A. Pera, M. La Marca, and G. Vallini. 1996. Effects of humic acids from compost-stabilized green waste or leonardite on soil shrinkage and microaggregation. *Compost Science and Utilization*. 4(4):40–46.

Claassen, V., and M. Hogan, 1998. *Generation of water-stable soil aggregates for improved erosion control and revegetation success*. California Department of Transportation. RTA # 53X461.

Epstein, E. 1997. *The science of composting*. Technomic Publishing Co., Inc., Lancaster, Pennsylvania. 487 pages.

Ettlin, L., and B. Stewart. 1993. Yard debris compost for erosion control. *BioCycle*. 34(12):46–47.

Fulford, B.R., W.F. Brinton, and R. DeGregorio. 1993. Composting grass clippings. *BioCycle*. 33(5):40.

Hamilton, T., G. Morris, and R.M. Setti. 1993. *Coastal revegetation with compost and xeriscape technology*. International Erosion Control Association, pp. 193–202.

Hegberg, B.A., W.H. Hallenbeck, G.R. Brenniman, R.A. Wadden. 1991. “Setting standards for yard waste compost.” *BioCycle*. 32(2):58–1.

Henry, C.L., M. Knoop and K. Cutler-Talbott. 1991. *Technical information on the use of organic wastes as soil amendments*. Solid Waste Compost Council. 250 pages.

Henry, G. and D. Bush. 1996. Applying yard trimmings compost to Florida highways. *BioCycle*. 37(2):53–54.

Grobe, K., and M. Buchanan. 1993. Agricultural markets for yard waste compost. *BioCycle*. 34(9):33–36.

Gurkewitz, S. 1989. Yard debris compost testing. *BioCycle*. 30(6):58–60.

Kelly, S. 1993. Large scale yard waste composting. *BioCycle*. 34(9):30–32.

Logsdon, G. 1993. Compost the green (grass) monster. *BioCycle*. 34(9):48–50.

Metro 1994. *Summary of projects using yard debris compost for erosion prevention and control. Final report.* June 1994. Solid Waste Department, Planning Department 600 NE Grand Ave. Portland, OR 97232-2736.

Minnesota Department of Transportation. *Specifications – Section 3890 – Compost*. Maplewood, MN, 1987.

Pollock, D., and B. Moreno. 1993. *Evaluation of compost on landscaped freeway roadsides*. California Department of Transportation. 20 pages, plus appendices.

Press, C.M., W.F. Mahaffee, J.H. Edwards, and J.W. Kloepper. 1996. Organic by-product effects on soil chemical properties and microbial communities. *Compost Science and Utilization*. 4(2):70–80.

Sollenberger, D.A. 1987. *Evaluation of compost and co-compost materials for highway construction – Phase I.* California Department of Transportation. Contract No. R86TL07.

Storey, B.B., J.A. McFalls, and S.H. Godfrey. 1995. *The use of compost and shredded brush on rights-of-way for erosion control: Final report.* Texas Transportation Institute. Texas A&M University System. College Station, Texas. Contract No. 0-1352.

Appendix A: Tables 4–9

Laboratory Analysis of Compost Materials From Statewide Compost Survey

Table 4. Macronutrient concentrations of compost materials, by producer. See Appendix C for key to abbreviations and acronymns.

		Total Concentrations – Macronutrients						
Producer code #	Source	% N	% P	% K	% Ca	% Mg	% Na	% S
1	GMC	1.35	0.32	1.27	1.84	0.48	0.16	17.10
2	GMC	1.47	0.20	0.91	2.07	0.53	0.16	2.20
4	GMC	1.08	0.18	0.61	1.96	0.66	0.14	6.10
5	GMC	0.92	0.26	0.46	2.16	0.77	0.09	12.70
6	GMC	1.32	0.32	1.20	2.49	0.57	0.27	36.40
7	GMC	1.20	0.27	1.02	1.68	0.44	0.24	11.20
10	GMC	0.96	0.20	0.68	1.62	0.39	0.27	58.80
12	GMC	1.06	0.28	0.99	1.86	0.51	0.10	23.10
14	GMC	1.34	0.24	0.67	2.64	0.63	0.06	11.90
15	GMC	1.32	0.30	1.01	1.55	0.45	0.26	16.80
16	GMC	1.00	0.19	0.74	1.38	0.68	0.15	9.60
17	GMC	1.32	0.26	0.80	1.68	0.59	0.10	4.20
22	GMC	1.71	0.27	0.45	2.19	0.54	0.04	2.20
24	GMC	1.42	0.27	0.92	3.08	1.07	0.11	74.40
111	CCM	1.50	1.06	0.53	2.90	0.63	0.17	131.20
119	CCM	2.73	1.28	0.26	1.77	0.38	0.11	53.90
120	CCM	1.92	2.10	0.35	2.55	0.50	0.13	88.10
121	CCM	1.56	1.60	0.54	3.01	0.42	0.20	112.50
208	AGC	1.68	1.72	2.98	4.36	1.17	0.53	123.10
209	AGC	1.50	1.26	1.76	2.26	0.60	0.39	169.40
213	AGC	0.73	0.47	1.69	2.26	0.93	0.27	83.10
303	Other	0.89	0.14	0.62	1.53	0.37	0.16	14.30
323	Other	2.30	0.41	2.87	0.91	0.40	0.04	16.90

Table 5. Micronutrient concentrations and other chemical characteristics of compost materials, by producer. See Appendix C for key to abbreviations and acronymns.

		Total Concentrations – Micronutrients					Half sat %	Other Chemical Characteristics			
Producer code #	Source	ppm Cu	ppm Zn	ppm Mn	ppm Fe	ppm B		TEC	pH	Qual lime	ECe
1	GMC	128	226	249	11970	42	45	371	7.7	low	16.0
2	GMC	48	145	199	8057	48	116	513	7.9	low	5.1
4	GMC	56	135	459	20510	68	48	433	7.3	low	6.4
5	GMC	54	130	430	19620	67	50	481	7.2	low	7.6
6	GMC	119	287	277	14180	84	52	456	7.8	med	13.6
7	GMC	40	111	221	7853	45	91	456	7.4	none	6.3
10	GMC	106	239	340	36850	69	61	356	7.3	low	12.9
12	GMC	59	168	249	12440	64	38	398	7.7	med	13.8
14	GMC	85	191	383	12600	75	56	573	8.0	med	6.3
15	GMC	46	207	252	11040	49	62	572	8.0	low	14.0
16	GMC	41	127	248	12410	41	69	521	7.9	low	7.7
17	GMC	114	185	501	14350	46	62	487	7.6	low	5.5
22	GMC	71	181	629	9817	61	95	691	7.8	low	2.6
24	GMC	88	223	377	16540	59	52	490	7.5	med	13.8
111	CCM	290	490	288	30030	70	42	976	7.4	med	21.5
119	CCM	202	337	404	11770	37	112	673	6.7	low	9.3
120	CCM	256	795	180	11420	28	26	388	6.1	x	21.2
121	CCM	298	525	263	21920	57	84	729	7.7	low	15.2
208	AGC	154	379	636	17420	116	38	243	8.2	h	37.5
209	AGC	285	327	553	7895	42	46	448	8.9	low	31.2
213	AGC	55	132	344	13930	59	32	524	8.9	med	26.9
303	Other	51	116	185	10010	40	61	355	7.3	low	5.4
323	Other	33	38	120	4582	60	71	748	7.6	low	9.0

Table 6. Available nutrient concentrations, by producer. See Appendix C for key to abbreviations and acronymns.

		Available Nutrient Levels									
		NaCl extract					Bicarbonate extract	DTPA extract			
Producer code #	Source	ppm NO_3-N	ppm NH_4-N	ppm K	ppm Ca	ppm Mg	ppm PO_4-P	ppm Cu	ppm Zn	ppm Mn	ppm Fe
1	GMC	485	11	8434	3133	925	231	5.8	50.0	50.0	226.0
2	GMC	36	12	8444	3798	2174	358	6.0	62.0	94.0	198.0
4	GMC	40	197	5191	4005	1254	128	4.2	24.0	88.0	106.0
5	GMC	962	14	4541	5802	1787	209	7.8	48.0	50.0	204.0
6	GMC	25	248	8571	3168	860	218	16.2	98.0	64.0	364.0
7	GMC	27	10	7529	3294	1540	281	1.8	42.0	110.0	62.0
10	GMC	163	79	5784	3791	1147	86	12.4	94.0	32.0	754.0
12	GMC	476	360	7283	3478	698	278	3.4	54.0	36.0	140.0
14	GMC	84	616	6057	6057	1550	269	6.6	46.0	76.0	140.0
15	GMC	165	13	8369	4990	1582	524	5.4	58.0	56.0	172.0
16	GMC	25	94	6501	4323	1966	390	3.6	34.0	56.0	70.0
17	GMC	24	81	7012	3728	1784	336	5.4	62.0	170.0	156.0
22	GMC	263	19	3963	9263	2097	307	4.0	50.0	74.0	202.0
24	GMC	18	240	6852	5271	1845	268	7.6	64.0	122.0	490.0
111	CCM	793	3298	3750	10767	1344	200	43.2	176.0	46.0	664.0
119	CCM	1335	3904	2141	5376	1690	762	29.0	104.0	118.0	280.0
120	CCM	1187	1972	1781	2271	1414	1688	40.4	98.0	10.0	56.0
121	CCM	488	3305	3922	7380	1258	268	31.6	148.0	38.0	444.0
208	AGC	20	7	5902	2446	1206	650	17.0	152.0	54.0	564.0
209	AGC	26	682	12682	1453	1384	2236	102.0	152.0	136.0	158.0
213	AGC	532	371	13619	1412	663	682	4.2	34.0	48.0	128.0
303	Other	21	229	4983	2781	1191	105	1.2	32.0	68.0	74.0
323	Other	21	1180	22064	1317	1641	1089	1.6	18.0	86.0	148.0

Table 7. Available nutrient concentrations, by producer. See Appendix C for key to abbreviations and acronymns.

Producer code #	Source	Sat ext ppm B	Sat ext % ECe Na	Sat ext meq/L Cl	Dil acid % Fe
1	GMC	1.8	19.4	70.4	0.1
2	GMC	0.7	8.0	21.8	0.2
4	GMC	1.0	12.7	39.4	0.2
5	GMC	2.8	2.6	7.0	0.2
6	GMC	5.1	41.5	66.2	0.2
7	GMC	0.5	17.7	33.8	0.2
10	GMC	2.3	50.4	62.0	1.0
12	GMC	5.6	21.0	59.2	0.2
14	GMC	2.4	3.2	22.0	0.2
15	GMC	0.8	42.0	85.9	0.2
16	GMC	0.4	17.7	49.3	0.1
17	GMC	1.0	6.3	25.4	0.2
22	GMC	1.0	0.9	2.3	0.1
24	GMC	2.2	18.8	62.7	0.3
111	CCM	4.1	38.7	56.3	1.2
119	CCM	1.2	9.1	9.2	0.5
120	CCM	1.5	32.0	12.7	0.4
121	CCM	2.3	22.2	33.1	1.5
208	AGC	7.6	81.7	197.0	0.7
209	AGC	7.8	102.6	107.0	0.1
213	AGC	5.4	67.0	98.6	0.2
303	Other	0.6	11.3	24.6	0.2
323	Other	0.9	1.2	6.3	0.2

Table 8. Physical and chemical characteristics of compost materials, by producer. See Appendix C for key to abbreviations and acronymns.

				1/2" Minus Material							
Producer code #	Source	Wt retained 1"	Wt retained 1/2"	Bulk dens, lb/cu yd	Moisture %	Water fraction, lb/cu yd	Dry matter, lb/cu yd	Organic fraction, lb/cu yd	Mineral fraction, lb/cu yd	Organic fraction, %	C:N ratio
1	GMC	0	0	1506	33.6	506	1000	292	708	29.2	12.0
2	GMC	0	2.6	806	50.5	407	399	286	113	71.8	27.1
4	GMC	0	0.9	1094	24.1	264	830	283	547	34.7	17.5
5	GMC	0	3.4	1653	44.5	736	917	243	674	26.5	16.0
6	GMC	0	0.4	1166	35.6	415	751	277	474	36.9	15.5
7	GMC	0	4.5	797	40.5	323	474	285	190	60.0	27.8
10	GMC	0	1.5	1088	38.8	422	666	278	388	41.8	24.2
12	GMC	0	1.5	1370	26.4	362	1010	263	745	26.1	13.7
14	GMC	0	0.8	1241	33.3	413	828	343	485	41.4	17.2
15	GMC	0	0.5	1459	47.9	699	760	271	490	35.6	15.0
16	GMC	0	1.1	935	35.7	334	601	283	319	47.0	26.1
17	GMC	0	2.5	1017	32.4	330	687	283	404	41.2	17.3
22	GMC	0	1.2	1110	56.6	628	482	299	183	62.0	20.1
24	GMC	0	0.4	1119	31.7	355	764	288	476	37.7	14.7
111	CCM	0	0.3	1501	29.6	444	1060	311	746	29.4	10.9
119	CCM	0	2.2	1036	56.1	581	455	338	117	74.3	15.1
120	CCM	0	3.5	1671	22.5	376	1300	363	932	28.0	8.1
121	CCM	0	2	973	43.9	427	546	242	303	44.4	15.8
208	AGC	0	0	1438	20.7	298	1140	409	731	35.9	11.9
209	AGC	0	0	1090	24.3	265	825	136	689	16.5	6.1
213	AGC	0	0.7	1608	20.7	333	1280	214	1060	16.8	12.8
303	Other	0	0.7	891	13.7	122	769	303	466	39.4	24.6
323	Other	0	1	1043	43.8	457	586	491	95	83.8	20.2

Table 9. Physical characteristics of compost materials, by producer. See Appendix C for key to abbreviations and acronymns.

Producer code #	Source	% passing 9.51 mm	% passing 6.35 mm	% passing 4.75 mm	% passing 2.38 mm	% passing 1.00 mm	% passing 0.50 mm
1	GMC	98.9	97.1	94.9	83.4	61.7	41.7
2	GMC	92.7	84.7	78.1	64.2	43.1	24.1
4	GMC	100	96.9	92.3	76.2	53.8	36.2
5	GMC	98.6	93	88.8	69.9	34.3	11.2
6	GMC	100	100	96.6	84.3	54.9	33.8
7	GMC	98.6	93.7	86.7	72.7	52.4	35
10	GMC	96.9	86.6	81.9	65.4	42.5	26.8
12	GMC	100	96.1	91.5	82.4	64.1	45.8
14	GMC	96.6	93.9	91.6	76.5	53.1	34.6
15	GMC	96.2	77.9	70.2	50.4	25.2	8.4
16	GMC	97.3	86.3	82	71.6	54.6	40.4
17	GMC	98	87.2	81.8	65.5	44.6	29.7
22	GMC	93.6	90.9	88.2	72.7	46.4	19.1
24	GMC	100	100	97.5	80.8	55.8	37.5
111	CCM	100	98.9	96.3	82.5	57.1	39.2
119	CCM	92	81.8	72.7	46.6	21.6	8
120	CCM	100	97	89.3	62.4	32.9	17.1
121	CCM	93.1	81.8	73.6	55.3	26.4	11.9
208	AGC	100	98.9	98.9	94.7	66.8	44.2
209	AGC	100	100	98.6	93.8	66	37.5
213	AGC	100	97.1	95.6	85.3	64.7	44.6
303	Other	99.4	98.1	94.3	82.3	62.7	47.5
323	Other	100	99.2	98.4	49.2	34.7	23.4

Appendix B: Draft Specifications

Interim Caltrans Specification for Compost

Compost shall be derived from green material consisting of chipped, shredded, or ground vegetation; clean, processed, recycled wood products; Class A, exceptional-quality biosolids composts, as required by U.S. EPA regulations (40 CFR, Part 503c); or a combination of green material and biosolids compost. The compost shall be processed or completed to reduce weed seeds, pathogens and deleterious material, and shall not contain paint, petroleum products, herbicides, fungicides, or other chemical residues that would be harmful to plant or animal life. Other deleterious material, plastic, glass, metal, or rocks shall not exceed 0.1 percent by weight or volume.

A minimum internal temperature of 57°C shall be maintained for at least 15 continuous days during the composting process. The compost shall be thoroughly turned a minimum of five times during the composting process and shall go through a minimum 90-day curing period after the 15-day thermophilic composting process has been completed. Compost shall be screened through a maximum 6-mm screen.

The moisture content of the compost shall not exceed 35 percent. Moisture content shall be determined by California Test 226. Compost products with a higher moisture content may be used, provided the weight of the compost is increased to equal the weight of the compost with a moisture content of 35 percent. Compost will be tested for maturity and stability with a Solvita test kit. The compost shall measure a minimum of "6" on the maturity and stability scale.

Note: *The screen size and the maturity/stability measurement may change, depending on the intended use of the compost.*

Appendix C: Acronyms and Abbreviations

ac.............acre

AGC..........agricultural byproducts compost (manure, feathermeal, bedding)

bicarb........bicarbonate extract (Olsen test)

Ca.............calcium

CCM.........co-composted materials (biosolids/green materials compost)

CFR..........Code of Federal Regulations

cm............centimeters

Cu.............copper

cu.............cubic

CV...........coefficient of variation [(s/X)* 100]

dil acid......dilute acid extract

dS.............deciSiemens

DTPA........diethylenetriamine pentaacetic acid

ECe...........electrical conductivity measured on a saturated extract

extract.......the procedure of estimating the nutrient content of materials by mixing it with a specific solution and removing the solution for analysis

ft..............foot

GMC.........green materials compost

ha.............hectare

half sat %...the half saturation percentage is the percentage of water equal to half of the saturated capacity of the compost

in..............inch

K..............potassium

KCl...........potassium chloride

kg.............kilogram

l...............liter

m..............meter

meq..........millequivalent

Mg...........magnesium

mg............milligram

mm...........millimeter

N..............nitrogen

Na............sodium

NaCl.........sodium chloride

NH_4-N.......ammonium nitrogen

NO_3-N.......nitrate nitrogen

O..............oxygen

P..............phosphorus

pH............negative log of hydrogen ion activity

PO_4-P........phosphate phosphorus

ppm..........parts per million

S..............sulfur

s...............standard deviation

sat ext........saturation extract

SO_4...........sulfate

TEC..........total exchangeable cations (measured on saturation extract, except for sodium)

X..............mean

yd.............yard

Zn............zinc