ABOUT COMPOST

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The following information was collected to help us understand how to evaluate the quality of compost and the statewide compost production space. This document presents definitions of terms, procedures for making compost, industry certifications, and the spectrum of compost quality including common contaminants. It should be noted that much of the documentation to date on compost quality relates to its use in farming and row crops, not rangeland application. What we have learned about this is discussed in regards to assessing compost quality.

DEFINITION OF TERMS

California Code of Regulations, Title 14, Natural Resources Division 7, Chapter 3.1 entitled *Compostable Materials Handling Operations and Facilities Regulatory Requirements* and Chapter 3.2 entitled *In-Vessel Digestion Operations and Facilities Regulatory Requirements* apply to composting operations

Section 17852 of Article 1 of Chapter 3.1, Division 7 of Title 14 of the California Code of Regulations provides 43 definitions of terms used in the regulations on composting. Several are highlighted here for convenience and to streamline the use of these terms throughout this report.

Feedstock – any compostable material used in the production of compost or chipped and ground material including, but not limited to, agricultural material, green material, vegetative food material, food material, biosolids, digestate and mixed material. Feedstock shall not be considered as either additives or amendments.

Additives – material mixed with feedstock or active compost in order to adjust the moisture level, carbon to nitrogen ratio, or porosity to create a favorable condition. Additive include, but are not limited to, fertilizers and urea. Additives do not include septage, biosolids, or compost feedstock.

Amendments – materials added to stabilized or cured compost to provide attributes for certain compost products, such as product bulk, product nutrient value, product pH, and soils blend. Amendments do not include septage, biosolids, or compost feedstock.

Agricultural Material – material of plant or animal origin, which results directly from the conduct of agriculture, animal husbandry, horticulture, aquaculture, silviculture, vermiculture, viticulture and similar activities undertaken for the production of food and fiber for human or animal consumption or use which is separated at the point of generation, and which contains no other solid waste. With the exception of grape pomace or material generated during nut or grain hulling, shelling, and processing, agricultural material has not been processed except at its point of generation and has not been processed in a way that alters its essential character as a waste resulting from the production of food or fiber for human or animal consumption or use. Material that is defined in section 17852 as “food material” or “vegetative food material” is not agricultural material . Agricultural material includes, but is not limited to manure, orchard and vineyard prunings, grape pomace, and crop residues.

Green Material – any plant material except food material and vegetative food material that is separated at the point of generation, contains no greater than 1.0 percent of physical contaminants by dry weight, and meets the requirement of section 17868.5. Green material includes, but is not limited to, tree and yard trimmings, untreated wood wastes, natural fiber products, wood waste from silviculture and manufacturing, and construction and demolition wood waste…. Agricultural material that meets this definition of "green material" may be handled as either agricultural material or green material.

Physical Contaminants – human-made inert material contained within compostable material, digestate, or compost, including, but not limited to, glass, metal, and plastic.

Active Compost – compost feedstock that is in the process of being rapidly decomposed and is unstable. Active compost is generating temperatures of at least 50 degrees Celsius (122 degrees Fahrenheit) during decomposition; or is releasing carbon dioxide at a rate of at least 15 milligrams per gram of compost per day, or the equivalent of oxygen uptake.

Curing – the final stage of the composting process that occurs after compost has undergone pathogen reduction, as described in section 17686.3, and after most of the readily metabolized material has been decomposed and stabilized.

Digestate – the solid and/or liquid residual material remaining after organic material has been processed in an in-vessel digester, as defined in section 17896.2(a)(14). Digestate intended to be composted pursuant to Chapter 3.1 may only be handled at a facility that has obtained a Compostable Material Handling Facility Permit pursuant to section 17854.

Biosolids – solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in ca treatment works…

The California Environmental Protection Agency's Department of Resources Recycling and Recovery, known as CalRecycle, is the State's leading authority on recycling, waste reduction (including organics management) and product reuse. They provide a more in depth definition of both compost and mulch which are commonly confused:

Compost - the end product resulting from the controlled biological decomposition of organic material from a feedstock into a stable, humus-like product that has many environmental benefits. Composting is a natural process that is managed to optimize the conditions for decomposing microbes to thrive. This generally involves providing air and moisture, and achieving sufficient temperatures to ensure weed seeds, invasive pests, and pathogens are destroyed. A wide range of material (feedstock) may be composted, such as yard trimmings, wood chips, vegetable scraps, paper products, manures and biosolids. Compost may be applied to the top of the soil or incorporated into the soil (tilling). Finished compost bears little resemblance to the original materials from which it was created. Mature compost is normally dark brown in color and should have an even texture and a pleasant, earthy aroma. Compost products may vary since the properties of any given compost depend on the nature of the starting feedstocks and the conditions under which they were processed. CalRecycle requires all permitted and otherwise authorized facilities to test their finished compost to ensure it meets specific requirements and is safe for humans and the environment. Fully mature compost can break down no further and may be safely applied directly to existing landscapes and sensitive garden plants.

Mulch - a layer of material applied on top of soil. Examples of material that can be used as mulch include wood chips, grass clippings, leaves, straw, cardboard, newspaper, rocks, and even shredded tires. Benefits of applying mulch include reducing erosion and weeds and increasing water retention and soil vitality. Whenever possible, look for mulch that has been through a sanitization process to kill weed seeds and pests. Sheet mulching is a process in which multiple layers of materials are used to provide an impermeable barrier to weeds while allowing water to soak through. The mulch layers break down slowly, adding nutrients to the soil over time.

COMPOSTING PRODUCTION PROCESS

The peer-reviewed publication entitled Field Guide To On-Farm Composting (NRAES-114) issued in 1999 and developed through a cooperative agreement between the Natural Resource, Agriculture and Engineering Service (NRAES) and the United States Department of Agriculture Natural Resources Conservation Service (NRCS) was utilized as a reference for technically accurate guidance on characteristics of quality compost and the proper procedures for making it. Portions of this publication, which is intended to be used in the field, are excerpted from the On-Farm Composting Handbook (NRAES-54) and are primarily focused on small composting operations occurring in aerobic environments. These resources provide detailed instruction on making compost and troubleshooting a specific operation. The next section is provided just as an overview to get a general understanding of the compost making process and what the recommendations are for creating a quality soil amendment product.

The degradation of organic material is an ongoing, natural biological process that occurs as a result of oxidation and comsumption by naturally-occurring microorganisms. Once organic material (feedstocks) are piled together, microbial respiration causes the temperature of the pile to increase to approximately 120 – 140^{o}F within a few hours and remain in that range for several weeks as “active compost”. A variety of microorganisms, including beneficial actinomycetes, bacteria, fungi, algae and protozoa consume oxygen and settling material expels air from the pore spaces in the pile. Anaerobic conditions are likely to develop unless air is manually introduced to the pile through turning processes, forced air (blowers and fans) or by structuring the pile in such a way that is conducive to passive air movement throughout the pile. As the active composting degradation process slows over time, temperatures gradually decrease to 100 ^{o}F and then to ambient air temperature. What follows is a curing period where materials continue to break down but at a much slower rate where the compost is able to be piled without being regularly aerated.

The composting process does not stop until the last nutrients are consumed by the last remaining organism, however, compost is judged to be "done" and able to be utilized for beneficial purposes long before this. Characteristics such as its carbon-to-nitrogen (C:N) ratio, oxygen demand, temperature and odor determine when compost is considered stable and ready to be utilized. Generally, the composting process from start (raw material feedstocks) to finish (cured compost) may take anywhere from 1 to 2 months depending on the volume and specific methodology used.

If compost dries out or if piles are built too large (over 12 feet high), it is possible for the internal heat of the pile to initiate a chemical reaction which can lead to spontaneous combustion. Risk of a fire starting in a compost pile can be decreased if piles are built to be longer versus taller and regularly moistened. Having a water source nearby and creating a fire break in any adjacent vegetation are considered good precautions.

METHODS FOR MAKING COMPOST

There are specific methods for making compost in either aerobic or anaerobic environments, although aerobic composting is much more common particularly for smaller scale operations.

Making Compost in Anaerobic Conditions

In an anaerobic composting process, there is a lack of gaseous oxygen, which is prevented from entering the system by physical containment in sealed tanks. Anaerobic digestion creates heat just like aerobic composting, but the temperature of the digestion does not get hot enough to kill pathogens or weed seeds. Instead, this is accomplished through the acidic environment (similar to that in the stomach, hence the term "digester") that an entirely different set of bacteria and fungi creates via putrefaction. The time period to kill off dangerous microorganisms is much longer for anaerobic digestion, typically up to a year, which is why there are typically more than one containers going at once. A major benefit of anaerobic composting is that is it much less labor intensive and basically can be left alone. In addition, methane that is generated from the decomposition process can be captured and used to power engines or produce heat.

Making Compost in Aerobic Conditions

NREAS-114 identifies the following basic approaches to making compost on farms in aerobic environments including:

- passive or open-pile composting
- aerated static pile system using perforated pipes
- windrow composting using a loader or specialized windrow turners
- a variety of contained, in-vessel, systems

The volumes and types of feedstock material will often determine which method is implemented. For example, if manure is one of the feedstocks, it is recommended that the pile height not exceed 3 – 4 feet since manure, from horses particularly, has such a high temperature potential, and keeping piles small helps dissipate excess heat.

Passive or open-pile composting

Passive or open-pile composting is the lowest maintenance method of making compost as it does not include a turning regime. This process requires small sized piles so that their weight does not cause compaction. This is important because in a passive system, air must be able to passively enter the pile via the wind or from the convective flow produced from warm air rising from the interior of the pile drawing cooler fresher air in from the sides and bottom. This method would be best suited for a small farm operation with limited staff. The largest operational expenses of making compost are the labor and equipment used to form and mix the initial piles. A disadvantage of passive or undisturbed composting is the likelihood of anaerobic conditions being created from excess water or compaction, and the pile becoming very odorous.

Aerated static piles

Creating aerated static piles involves embedding open-ended perforated pipes in a layer of porous material such as straw or woodchips at the base of each pile. As the hot gases from the interior of the pile rise, air is drawn into the pipes to replace that air in the interior sections. Forced air can also be pumped in the pipes to allow for longer, larger piles. With this method, the pile needs a structure such that good porosity can be maintained throughout the pile for the duration of the composting process. For this reason, not all feedstocks are appropriate for this method and the initial mixing of the pile is critical upon setup and placement. Aerated static piles are typically 5 – 8 feet in height. This method is utilized by Flag Is Up Farms' compost operation.

Turned piles or windrows

The most common method of on-farm composting is turned piles or windrows (elongated piles). Turning reestablishes the porosity in the pile to improve air exchange, increases mixing and even distribution of feedstocks, and alternates the portions of the pile that are directly exposed to the wind and sun. This creates a more evenly degraded pile overall and allows the interior temperatures to achieve high enough levels to destroy weed seeds, pathogens and fly larvae. Turning is typically performed by loaders or specialized windrow turners. The volume of compost being made will likely determine when it becomes more cost-effective to invest in specialized turning equipment that can process piles more quickly than a laborer manually turning a pile with a loader. Temperature and turning requirements include maintaining a temperature between 130 – 150^{o}F for 15 days, turning the pile every three to five days. Proper pile aeration maintains optimum oxygen conditions for aerobic bacteria activity. If aeration is insufficient at any point in the process, anaerobic conditions will develop and the pH of the pile may drop to 4.5 hindering the bacteria and therefore the composting process.

In-Vessel Systems

In-vessel composting confines active compost in a building, container or vessel such as an insulated drum. Most in-vessel methods rely on forced aeration and mechanical turning techniques to speed up the composting process.

COMPOST MAKING EQUIPMENT

To make and apply compost to rangelands in bulk quantities, the minimal amount of equipment required is a front-end loader for managing feedstocks and turning piles, a hose for water application, a thermometer for temperature readings and some type of mechanical spreading equipment for compost application such as a common manure spreader. The larger the quantity of material you are managing, the more it becomes necessary and cost-effective to use larger are more specified pieces of compost making equipment such as windrow turners, compost spreaders, screens and shakers. Below are some examples of these types of equipment.

Mighty Mike windrow turner

Frontier tow-behind windrow turner

Aeromaster tow-behind windrow turner

Machine Works CT-10 windrow turner

BBI Endurance Pull Type Spreader

EZ-Screen 409 Trommel Drum Screen

Common Composting Equipment, Costs and Suppliers

Equipment Supplier	Equipment Description	Equipment Model	Cost	Notes
Frontier Industrial Corporation **Russ Fowler** (559) 259-5429 fowlerruss@sbcglobal.net	**Windrow Turner** 80-inch row width (also tows behind and adjacent to tractor path)	Mighty Mike MM-80	$15,950	According to Russell Chamberlin, there is a farmer in Goleta who has a Mighty Mike to consider renting from
	Tow Behind **Windrow Turner** 10-inch width	TB-10	$34,400	-
	Tow Behind **Windrow Turner** 12-inch width	TB-12	$36,850	According to Russell Chamberlin, there is a TB-12 located in Hanford, CA.
Salford BBI	Endurance Pull Type Hydraulic Compost **Spreader**	00EPH	NA	Different hopper styles from 10-28 feet long
EZScreen http://www.ez-screen.com/ez-409-trommel	**Trommel Screen**	EZ409	$79,900	-
OMH Proscreen http://www.omhproscreen.com/topsoil-screener/slg-78/slg-78vf	**Vibrating Screen**	Desite SLG 78VF Topsoil Screener	$4,695	Vibratory system with feeder
Diamond A Oxnard (805) 857-3702 Greg Donlon gregd@ahern.com	**Spreaders**	varies	> $22,000	Gearmore.com

Composting Equipment for Rent

Equipment Supplier	Equipment or Service Description	Rental Cost	Notes
Stan of Crop Production Services Goleta (805) 550-3422 (cell)	**Spreader** Ground driven, needs 15-25 hp tractor	$125/day includes delivery	Referred by Russell Chamberlin, has 2 spreaders
Gus Bar Santa Maria	**Spreading Services**	-	Referred by Chris Thompson, brokers compost & gypsum, delivers and spreads
John Wick Bay Area	**Spreader**	Free	Delivery and labor to operate not included
Tenant **Chamberlin Ranch** Los Olivos	**Spreader** (17-yard)	-	Referred by Russell Chamberlin
Diamond A Oxnard (805) 857-3702 Greg Donlon gregd@ahern.com	**Tractors** 25–50 hp, and 60–100 hp	$250 – $300/day	-
Sun Coast Rentals Carpinteria (805) 684-4173	**Skip Loaders**	$240/day	Delivery Costs $100 each way for daily rental, $50 each way for weekly rental

POTENTIAL CONTAMINANTS

Contamination of organic material feedstocks with inert materials such as plastic and glass is a common problem due to source separation issues. As the organic material content in the feedstock continues to degrade, pieces of plastic do not and either blow away in the wind or remain as trash at the site where the material is applied. Glass is very slow to degrade and can be a safety hazard. At the least, a visual inspection of a compost source is recommended to determine if it meets your particular standards for your use.

Other contaminants that may exist in compostable materials include pathogens, vectors/pests, chemical pollutants, avermectin (the most commonly used drug classification to eradicate intestinal worms from horses), weed seeds and/or weed free hay. Compost that has been produced pursuant to CalRecycle regulations and/or best management practices reaches temperatures that can eliminate pathogens and weed seeds, but it is prudent to have compost sampled and analyzed at an appropriate laboratory before applying it for a specific use.

Avermectins are a contaminant of particular interest, due to the high number of equestrian stables in Santa Barbara County and the potential for high-quality manure to be used as a feedstock. There is very little scientific literature available on the topic of active avermectin residue in compost. However, most studies find that composting decreases the concentration of avermectins such that the resulting compost can be used without negatively affecting local ecosystems. Manure samples from horses very recently treated with avermectins show levels of the active compounds concentrated enough to cause harm to smaller microorganisms, including worms. Within 24-days of the composting process, however, concentration decreases almost entirely. The environmental degradation associated with avermectin residue is a result from raw manure spreading. Proper composting is one of the best practices to use for manure management from animals recently de-wormed or under continuous de-worming.[1]

Another potential feedstock contamination concern is persistent herbicides. Few herbicides persist on vegetation and in the soil for months or years after initial application. In this context, the most likely sources of persistent herbicide contamination are as follows: Clopyralid, Aminopyralid, Aminocyclopyrachlor, and Picloram (all from the picolinic acid family). There are over 150 retail products in the U.S. containing these herbicides, but chemicals may appear on labels in different variations. They are most commonly marketed for use in hayfields, horse pastures, golf courses, right-of-ways, grain

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[1] Schwarz, Mary, and Jean Bonhotal. "The Fate of Ivermectin in Manure Composting." *Cornell University Soil and Crop Sciences* (2016): n. pag. Web.

[2] "Persistent Herbicide Information." *US Composting Council*. US Composting Council, 15 Jan. 2011. Web. 20 July

crops, and lawns as a means to kill unwanted broadleaf weeds.

These herbicides eventually break down through exposure to sunlight, soil microbes, heat, and moisture but some reports show this can take up to four years. Degradation is particularly slow in piles of manure and composts. These colorless, odorless herbicides pass unaltered during microbial digestion. Microbial digestion, such that occurs during composting, concentrates these pesticides, because the stock is processed as food but the chemical passes as waste. When compost containing these persistent herbicides is applied to fields or gardens, damage can occur. The damage most commonly manifests itself as stunted plant growth, reduced fruit set, cupping of leaves, and failure of secondary leaves to grow after the seedling emerges. It can also result in crop failure. This issue most directly affects new plantings of vegetable (especially legumes), fruit, and flower crops. Grasses are less likely to be affected.

Commercial composters can test for contamination, but the tests are time-intensive, expensive, and difficult. Instead, the US Composting Council (USCC) recommends that compost producers conduct regular plant growth testing. In circumstances of doubt, where it cannot be determined whether or not the compost contains this contaminant, the USCC suggests applying the compost to less-sensitive areas, such as grassland. Additionally, farmers and gardeners can conduct their own set of testing using a pot bioassay procedure: a set of sensitive seedlings are planted using premium grade potting soil and a handful of pots receives compost randomly sampled from the compost supply. If the plants treated with compost show any sign of abnormal growth as compared to the control pots, the compost is likely contaminated.[2],[3]

CalRecycle's website advises users to be wise compost consumers with an understanding that not all compost is created equal and that there is a range of different qualities of compost that may be available. CalRecycle realizes that some composters are under pressure to move materials from their sites and may sell materials that are not fully composted. If this is the case, the compost may need to sit for a few weeks before it can be used without damaging plants. Warning signs that a compost is immature and not ready for use include:

- **High temperature:** The compost should not be steaming or significantly warmer than ambient conditions.

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[2] "Persistent Herbicide Information." *US Composting Council*. US Composting Council, 15 Jan. 2011. Web. 20 July 2016.
[3] Dr. Davis, Jeanine, and Sue Ellen Dr. Johnson. "Herbicide Carryover in Hay, Manure, Compost, and Grass Clippings." *Oregon State University*. Small Farms Publications, Oct. 2009. Web. 20 July 2016.

- **Odor:** Strong smells of ammonia or other odorous or unpleasant compounds indicate that the product is not mature.
- **Visible feedstock:** You should not be able to see green materials, bits of food, or chunks of dirt.
- **Visible contamination:** A small amount of plastic or glass contamination is normal when feedstocks are from urban environments. CalRecycle regulations allow up to 0.05 percent contamination by weight in any sample. This can be hard to estimate, but you can be the judge of how much is too much based on where the compost will be used, whether children will have contact with the product, etc.
- **Woodiness:** Compost that is too woody may be great for mulch but not ideal for a planting medium.

OPTIMIZATION FOR CREATING COMPOST

Proper nutrient balance, particle size, moisture content, temperature and bulk density are necessary for optimum pile performance and odor reduction. The following are recommended conditions for active compost adapted from the On-Farm Composting Handbook (NRAES-54):

Parameter	**Target Range**
Carbon-to-nitrogen (C:N) ratio	20:1 - 40:1
Moisture content	40 – 65%
Oxygen concentration	> 5%
Particle size	0.5 – 2 inches in diameter
Pile porosity	>40%
Bulk density	800 – 1,200 lbs/cubic yard
pH	5.5 – 9.0
Temperature	110 – 150^{o}F

Particle Size - For optimal compost performance, feedstocks may need to be prepared by decreasing particle sizes via grinding or shredding to speed up the decomposition process by increasing the surface area, and adjusting the ratios of feedstock materials in order to maintain neutral pH. Temperature affects microbial diversity and also plays an important role in managing disease-causing pathogens such as bacteria, viruses, fungi and protozoa. Several days of pile temperature above 130^{o}F are recommended to destroy pathogens and weed seeds.

pH – Compost piles that become anaerobic or sour are likely to develop odors and contain alcohol and volatile organic acids. Anaerobic byproducts are detrimental to plants. A compost that has become anaerobic can easily be identified by its odor and acidic pH which may be near 3.0. This situation can be corrected by stacking the compost in smaller pile thereby allowing the material to air out and compost further.

Use of wet, high-nitrogen feedstocks, such as food residuals, apple and grape pomace and waste potatoes may require amendment with wood ash, kiln dust, lime mud or other liming products to raise the initial pH of the mix. Compost feedstock that have a high lime or alkaline content such as some animal beddings, act to buffer a low-pH feedstock.

Temperature - Compost process temperatures should be monitored and recorded frequently with a dial thermometer with a 3- to 5-foot stem and a temperature range of 0 – 200^{o}F. Temperature testing is recommended at 1- and 3- foot depths along both sides of the windrow at 20-foot intervals.

Temperature is the primary measure for monitoring the composting process because the heat produced is directly related to the amount of microbial activity occurring. Abnormally low temperature signal that aerobic microbial activity has declined, or could be caused by low pile moisture or weather conditions.

The University of Maine Compost School recommends that piles or windrows should be turned:

- at approximately 150^{o}F and
- if the temperature drops without cause, or
- if the difference between 1-foot and 3-foot temperature readings is greater than 20^{o}F

SPECTRUM OF COMPOST QUALITY

There appears to be a wide range in the spectrum of quality for different composts that are produced. Making compost well requires daily observation, really understanding the science behind what is occurring in the pile and continually making adjustments in response to those observations.

Fundamentally, a consumer wants a compost free of inert contaminants such as plastic and glass, and one that is "finished", and no longer considered "active" compost. Finished compost is still decomposing but at a much slower rate and at a much lower temperature than active compost.

The following are common laboratory analyses for determining whether a compost is mature and ready for application as presented in NRAES-114 publication:

i. Oxygen consumption – should be low in a mature compost

ii. Carbon Dioxide respiration – should be low in a mature compost

iii. Self-heating ability - should be low

iv. Redox potential - should have a high oxidation/reduction value

v. Nitrate to Ammonia ratio – should have a high ratio greater than 1

vi. Humus test – should have a relatively high proportion of low- to high-weight humus compounds

vii. Growth test – cress, barley, green bean, or radish seeds should germinate in a compost at the proper time and produce vigorous, healthy plants. The presence of phytotoxic (plant-harmful) materials, such as soluble salts, volatile organic acid and heavy metals impedes seed germination and root growth.

viii. Dewar maturity test – measures heating potential of a compost in a special flask that contains the heat loss. Compost in the flask should not rise more than approximately 18^{o}F above ambient temperature after three to five days

ix. Nitrate and ammonia test – nitrate values should be no more than 200 ppm and no significant ammonia should be detectable in mature compost

x. Colorimetric respiration test - shows grades of compost respiration in a gel that changes color under exposure to the respired carbon dioxide from a sealed compost sample. A pre-specified color denotes a mature finished compost

The end-use for the material will steer what other kinds of characteristics one may want to know about. For instance, if the end use is for amending soils in preparation for planting a particular row crop, than plant nutrients, soluble salts and metals would likely be analyzed as it pertains to that particular crop's needs.

Below are some quality guidelines for the end use as a soil amendment (versus potting soil, potting media amendment, or top dressing) for the purposes of improvement of agricultural soils, restoration of disturbed soils, establishment and maintenance of landscape plants with pH of 7.2 or below as presented in NREAS-114.

Preferred Ranges for Various Compost Parameters When End-Use as a Soil Amendment

Compost Parameters	Units of Measure		Preferred Range[1]
Moisture Content	%, wet weight basis		40-45
Organic Matter Content	%, dry weight basis		35-70
pH	Units		5.5-8.0
Soluble Salts[2] (electrical conductivity)	dS/m (mmhos/cm)		<5
Particle Size or Sieve Size	Maximum aggregate size, inches		<1
Stability Indicator (respirometry)			**Stability Rating**
CO2 Evolution	Mg CO_2-C/g OM/day		Moderately stable to very stable
	Mg CO_2-C/g TS/day		
Maturity Indicator (bioassay)			
Percent Emergence	Average % of control		>80
Relative Seedling Vigor	Average % of control		>80
Select Pathogens	PASS/FAIL: per US EPA Class A standard, 40 CFR Section 503.32(a)	Fecal Coliform	Pass
		Salmonella	Pass
Trace Metals	PASS/FAIL: per US EPA Class A standard, 40 CFR Section 503.13, Tables 1 and 3	As, Cd, Cr, Cu, Pb, Hg, Mo, Ni, Se, Zn	Pass

[1]Dougherty, Mark. *Field Guide to On-Farm Composting*. Publication. Vol. 114. Ithaca: Natural Resource, Agriculture, and Engineering Service (NRAES), 1999. Print. NRAES.
[2]Preferred ranges for soluble salts in compost destined for application to row crops are lower than what is considered acceptable for compost destined for application to rangeland.

Analysis conducted according to the U.S. Composting Council Seal of Testing Assurance standards (see certifications section below) includes the following parameters:

- Moisture Content- Dust generation is more likely from a compost with low moisture content, which is a health consideration. Typically, the threshold for dust formation is 35% moisture or less.

- pH- A high pH level negatively affects seedling emergence and seedling vigor. Higher pH levels are often correlated with excess ammonia, a sign of immature compost. This can be remedied by a longer period of curing.

- Soluble salts- Excessive soluble salt content can prevent or delay proper seed germination and proper root growth, especially in salt-sensitive plants. However, finished compost can have a soluble salt content as high as 30 dS/m. To more correctly interpret this indicator, it's necessary to consider the use of compost. A compost with an elevated soluble salt content might be detrimental when applied to horticultural crop land, but still beneficial as a soil amendment on rangeland.

- Maturity Indicator- Lower ranges of this indicator can suggest the compost could negatively affect seed germination and root growth. This is also evidence of an immature compost, which can be remedied by a longer period of curing. It should be noted that the importance of this indicator depends upon application use of the compost. Land under horticultural use would be more negatively affected by application of this compost than land under other uses, such as orchards or vineyards in need of mulch.

According to CalRecycle regulations, all composting operations that sell or give away greater than 1,000 cubic yards of compost annually must analyze at least one composite sample of compost for every 5,000 cy produced or at least once annually if producing less than 5,000 cy/year. Sampling frequencies are more robust if the facility handles biosolids. The sample(s) must verify that the compost meets the maximum acceptable metal concentration limits, pathogen reduction requirements and physical contamination limits prior to removing compost from the site of production. If testing fails, compost is required to be further processed before being sold or removed from the site.

Soluble Salt Concentrations

Upon reviewing the results of laboratory testing on some of the local sources of compost we identified, we noticed what appeared to be elevated soluble salt concentrations. We looked into this particular parameter a little deeper.

According to a publication by William Darlington, a consultant at the Soil and Plant Laboratory, Inc. entitled *Compost – A Guide for Evaluation and Using Compost Materials as Soil Amendments*, soluble salt concentration is the concentration of soluble ions in solution, typically expressed as electrical conductivity in units of millimhos per centimeter or dS/m of a saturated extract of compost. Soluble nutrients, particularly potassium, calcium and nitrogen typically account for most of the salinity in compost products. Sodium is an undesirable soluble salt and should ideally account for less than25% of the total soluble salts in compost. Knowledge of soil salinity, compost salinity, and plant tolerance to salinity is necessary for the successful establishment of plant material. For most turf and landscape plantings the final salinity (EC) of the amended soil should be less than 4.0 dS/m. Higher soluble salt levels would likely require leaching irrigations.

We also reached out to Jeff Creque, Ph.D., Director of Rangeland and Agroecosystem Management for the Carbon Cycle Institute for insight into assessing parameters of compost destined for rangeland application. When asked about the soluble salt concentrations of 8 – 23 dS/m we were observing on lab analytical reports for local sources of compost Dr. Creque thought that these were acceptable, assuming there were no existing salinity issues in the ranglenad soils to which they are applied. He said that salts will quickly wash out of the compost with rain and be diluted by the large soil volume, but if the receiving soils are already high in salts one would want to select a compost with a lower total salt content.

Effects of Compost on Native Grassland Species

The American Carbon Registry's Methodology for Compost Additions to Grazed Grasslands (Oct. 2014) references Bremer, 2009 for a statement they make in Box 2 on page 11 that reads:

> *"Compost applications may lead to changes in the plant community (either positive or negative) due to impacts of compost on nutrient concentrations and hydrology of treated soils (Bremer, 2009). The protocol does not support application of compost to intact, healthy native plant communities. Whether a grassland constitutes a healthy native plant community is best determined in consultation with a qualified expert, as native plant communities are defined by their geography and are thus impacted by local conditions."*

The citation is from Bremer, E. 2009. Potential for Reductions in Greenhouse Gas Emissions from Native Rangelands in Alberta – Technical Scoping Document. Symbio Ag Consulting for Alberta Agriculture and Rural Development.

When Dr. Creque was asked for his input on native species to response to compost application, he clarified that the Carbon Cycle Institute recommends application of the protocol on grazed grasslands only, in collaboration with a rangeland professional and that it is their belief that there is little to zero risk of negative impacts to the plant community under the prescribed conditions, and significant potential for benefits, given the degraded state of much of California's (Eurasian annual-dominated) rangeland. Dr. Creque also recommended a review of the study by Ryals et al of the University of California Berkely, Department of Environmental Science, Policy and Management dated 2013 and entitled *Effects of organic matter amendments onntet primary productivitiy and greenhouse gas emmissions in annual grasslands*. Below is the abstract of that study.

"Abstract. Most of the world's grasslands are managed for livestock production. A critical component of the long-term sustainability and profitability of rangelands (e.g., grazed grassland ecosystems) is the maintenance of plant production. Amending grassland soils with organic waste has been proposed as a means to increase net primary productivity (NPP) and ecosystem carbon (C) storage, while mitigating greenhouse gas emissions from waste management. Few studies have evaluated the effects of amendments on the C balance and greenhouse gas dynamics of grasslands. We used field manipulations replicated within and across two rangelands (a valley grassland and a coastal grassland) to determine the effects of a single application of composted green waste amendments on NPP and greenhouse gas emissions over three years. Amendments elevated total soil respiration by 18% 6 4% at both sites but had no effect on nitrous oxide or methane emissions. Carbon losses were significantly offset by greater and sustained plant production. Amendments stimulated both above- and belowground NPP by 2.1 6 0.8 Mg C/ha to 4.7 6 0.7 Mg C/ha (mean 6 SE) over the threeyear study period. Net ecosystem C storage increased by 25–70% without including the direct addition of compost C. The estimated magnitude of net ecosystem C storage was sensitive to estimates of heterotrophic soil respiration but was greater than controls in five out of six fields that received amendments. The sixth plot was the only one that exhibited lower soil moisture than the control, suggesting an important role of water limitation in these seasonally dry ecosystems. Treatment effects persisted over the course of the study, which were likely derived from increased water-holding capacity in most plots, and slow-release fertilization from compost decomposition. We conclude that a single application of composted organic matter can significantly increase grassland C storage, and that effects of a single application are likely to carry over in time."

We also reached out to Dick Cameron, Associate Director of Science, Land Conservation Program at The Nature Conservancy for further information on potential negative impacts from compost application to nutrient poor grasslands. Mr. Cameron pointed us to a comment letter The Nature Conservancy submitted for the California Department of Food an Agriculture's Healthy Soils Incentives Program and white paper, *"Agronomic rates of compost application for California croplands and rangeland to support a CDFA Healthy Soils Incentives Program"* among some other useful references. The following is an excerpt from their comment letter:

*"**The rangeland compost application program should be implemented in phases, with near-term applications focusing on (1) scenarios that available science suggests are low risk and/or (2) carefully planned demonstration projects over a wider range of conditions to refine implementation guidelines and resolve uncertainties about ecosystem impacts.** Rangelands in the Western US are diverse physically and ecologically, and do not respond to perturbations predictably (i.e., they exhibit nonequilibrium dynamics) (Booker et al. 2013). As a result, soils and biological communities cannot be expected to respond uniformly to compost additions. California rangelands, especially grasslands and oak savannahs, are largely dominated by non-native species, notably annual grasses. Nevertheless, California's native floral diversity remains among the highest on earth, with ~6500 native and over 2100 endemic species (Jepson Flora Project (eds.). Jepson eFlora, http://ucjeps.berkeley.edu/IJM.html, accessed on January 20, 2016). Many of these California native plants depend on our rangeland ecosystems, which are home to over 50% of California's rare*

and endangered species. It is important to understand, however, that most of these native species found in rangelands currently persist in low relative abundances. ***A critical consideration for the potential use of compost additions in rangelands is that the native plant species richness of rangelands is often determined–paradoxically—by relatively nutrient-poor soil conditions*** *(Harpole et al. 2007). Furthermore, the diversity and abundance of native forb species is critical for sustaining our wild native pollinators, which in turn supply valuable pollination services both in rangelands and to neighboring crops (Chaplin-Kramer et al. 2011). Conservation of pollinators is now considered a national policy objective under the National Strategy to Promote the Health of Honeybees and Other Pollinators (https://www.whitehouse.gov/sites/default/files/microsites/ostp/Pollinator%20Health%20 Strategy%202015.pdf). Although there have been very few compost-addition studies, per se, completed in California's extensive rangelands that confirm long-term GHG benefits, it is well documented that higher nutrient levels (specifically, N and P) in many rangelands, particularly lower-productivity sites, results in shifts in plant community composition that favor invasive annual grass species and reduce native plant cover. In order to meet both the goal of increased carbon storage and avoid impacts to natural communities, we propose a phased approach to implementing the rangelands compost program, with the following elements:*

i. ***Appropriate determination of agronomic application rates.*** *Critical nutrient level thresholds for most rangelands have not been identified. However, as the white paper acknowledges, even low rates of N addition (~6 kg N/ha/year) can encourage growth of invasive annual species, leading to declines in native species in areas with low natural productivity. Sites with higher levels of soil P, typically found in association with higher N in composts, have also been documented to correlate with the absence of native species in extensive rangelands of California (Gea-Izquierdo et al. 2007). On the other hand, the addition of carbon (without N or P) can have neutral or even beneficial effects on native plant species composition in some California grasslands (Alpert 2010).* ***We therefore recommend that only higher C:N ratio composts be used in areas other than converted rangelands (defined below) until further information is available to ensure there are no adverse impacts to native biodiversity. We also recommend that application rates be limited to 3-5 tons/acre in areas other than converted rangelands or where ecologically-relevant studies (i.e., with similar climatic, topographic, species composition, and soil conditions) have documented no or low impacts to native species diversity and abundance.*** *By supporting a postdoctoral researcher (see below), TNC is committed to helping rapidly develop studies that would identify critical thresholds for a wider range of rangeland types, thereby helping expand the program responsibly over time and increasing opportunity for GHG mitigation.*

2. ***Implement Program in Phases.*** *We recommend that a first phase of the program be limited to rangelands that have been converted (e.g., plowed, irrigated, heavily seeded, or otherwise disturbed such that the natural communities and soil conditions are no longer present). In addition the first phase should include only the use of lower C:N ratio composts and include appropriate restrictions that will limit N and P runoff or impacts to sensitive areas.*

Concurrently, several demonstration sites across California along a gradient of soil, climate, species composition, and management conditions should be established and outcomes tracked. Following this first phase, we recommend that a second phase of the Program include unconverted rangelands that are naturally more mesic (i.e. wet) and with naturally rich soils and high productivity, provided that research currently underway and demonstration sites established through Healthy Soils conclusively demonstrate that compost amendments do not cause reduction of native species abundance or richness. A scientific panel should be assembled to assess these outcomes and make recommendations. Finally, future phases of the Program could include drier lower-productivity sites if outcomes from demonstration sites show that compost addition can lead to carbon storage 5 without resulting in loss of biodiversity (as measured by native species richness and abundance/cover, or per the recommendations of the panel).

3. ***Exclude application of compost in all sensitive ecological areas.*** *Areas that are considered sensitive to addition of nutrients and therefore not eligible for the Program are discussed on page 14 of the white paper. A more complete list should include, but not necessarily be limited to:*

   - *Serpentine and serpentine-influenced soil types;*
   - *Sites containing vernal pools;*
   - *Sites containing federal, state, and/or CNPS listed native plants; and/or animals that require low-stature rangelands for their life history, including but not limited to San Joaquin Kit Fox, Giant Kangaroo Rat, Tiger Salamander, and/or Burrowing Owl;*
   - *Wet meadows or other seasonally inundated rangelands, regardless of slope (e.g., floodplains);*
   - *Desert grasslands;*
   - *Coastal prairie;*
   - *Chaparral, coastal sage scrub, and other systems dominated by native shrubs;*
   - *Sites that have recently burned;*
   - *Sites in watersheds already impacted by N or P, unless appropriate mitigating practices are included (as described above).”*

COMPOST PRODUCT CERTIFICATIONS

Two known certification programs exist for finished compost product, both are voluntary.

Seal of Testing Assurance Certification

The US Composting Council (USCC) was established in 1990 and is a national nonprofit trade and professional organization promoting the recycling of organic materials through composting. They provide support for generators of organic residues, compost producers, policy-makers, regulators, professionals and product users for the purposes of advancing the industry. In 2000, USCC with leading compost research scientists in the US, set up a compost testing, labeling and information disclosure program called the Seal of Testing Assurance Program (STA), the development of which is described in the publication 'Test Methods for the Examination of Composting & Compost' (TMECC).

Compost facilities enrolled in the STA Program are required to regularly sample and test their compost products according to the following production volumes:

Volume of compost produced annually	Sample Collection Frequency
1 – 2,500 tons	1 sample per quarter (or less)
2,501 – 6,200 tons	1 sample per quarter
6,201 – 17,500 tons	1 sample every 2 months
17,501 tons and above	1 sample each month

Samples of compost are analyzed for the following properties at labs certified to perform the test methods specified in the TMECC publication:

- pH
- Soluble salts
- Nutrient content (Total Nitrogen, Phosphorus Pentoxide, Potassium Oxide, Calcium and Magnesium)
- Moisture content
- Organic matter content
- Bioassay (maturity)
- Stability (respirometry)
- Particle size (report only)
- Pathogen (Fecal Coliform or Salmonella)
- Trace metals (40 CFR Part 503 EPA regulated metals)

Some compost parameters, such as metals and pathogens, are regulated while others are product performance attributes linked to the recommended specific uses of the product. The USCC provides sampling instructions and Chain of Custody forms on their website.

There are three STA certified labs located in California:

- **A&L Western Laboratories, Inc.**
  1311 Woodland Ave., Suite 1
  Modesto, CA 95351
  Robert Butterfield, Laboratory Director
  209.529.4080
  Rbutterf@AL-Labs-West.com

- **Soil and Plant Laboratory**
  4741 E. Hunter Ave #A
  Anaheim, CA 92807
  www.soilandplantlaboratory.com

- **Soil Control Lab**
  42 Hangar Way
  Watsonville, CA 95076
  www.compostlab.comhttp://compostlab.com/
  Assaf Sadeh
  831.724.5422
  asadeh@controllabs.com

Participants pay an annual STA Program application fee of $800 per compost product ($600 for USCC members), and have the right to use the STA Program Logo. Directions for product use, an ingredient statement and the following written statement must accompany the logo:

"This compost product has been sampled and tested as required by the Seal of Testing Assurance Program of the United States Composting Council (USCC). Test results are available upon request by calling (Licensee Name) at (Telephone Number). The USCC makes no warranties regarding this product or its contents, quality, or suitability for any particular use."

Organic Materials Review Institute Certification

The Organic Materials Review Institute (OMRI) is a nonprofit organization founded in 1997 that provides technical support and training for professionals in the organic industry, and serves as an independent review of products and inputs intended for use in certified organic production and processing. OMRI reviews input products to determine compliance with the US National Organic Standards (NOS) published in the Federal Register (7 CFR Part 205). Materials that meet their standards are ‘OMRI Listed’ on the ‘OMRI Products List’.

Organic Input Materials Registration Program

The Organic Input Materials (OIM) Registration Program is a program of the California Department of Food and Agriculture that registers fertilizing materials to be used in organic crop and food production. Products claiming to be appropriate for use in organic production are verified to comply with the California Fertilizing Materials Law and Regulations and USDA National Organic Program Standards. Effective January 2012, OIMs distributed in California must be registered with the Fertilizing Materials Inspection Program (FMIP) whose inspectors conduct routine sampling and inspections to ensure that consumers receive what is guaranteed on the organic product label. According to CalRecycle’s website, compost that is suitable for use in organic production must be registered as an OIM with the CDFA and may use the CDFA Organic logo. Such products may also contain an approval from OMRI but this is no longer required in California. In addition, compost products that make claims for nutrient values must have a CDFA fertilizer label. Compost products that make no claims for organic production or for nutrient values may legally be sold without registration.