C O M P O S T
M A T U R I T Y
I N D E X

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Contents

Section 1
COMPOST MATURITY

Immature and poorly stabilized composts may pose a number of problems during storage, marketing and use. During storage these materials may develop anaerobic 'pockets' which can lead to odors, fire, and/or the development of toxic compounds. Continued active decomposition when these materials are added to soil or growth media may have negative impacts on plant growth due to reduced oxygen and/or available nitrogen or the presence of phytotoxic compounds. Compost maturity and stability are often used interchangeably. However, they each refer to specific properties of these materials. There have been and will continue to be efforts to develop and refine methods which evaluate stability and maturity, but no one universally accepted and applied method exists.

Stability refers to a specific stage or decomposition or state of organic matter during composting, which is related to the type of organic compounds remaining and the resultant biological activity in the material. The stability of a given compost is important in determining the potential impact of the material on nitrogen availability in soil or growth media and maintaining consistent volume and porosity in container growth media. Most uses of compost require a stable to very stable product that will prevent nutrient tie up and maintain or enhance oxygen availability in soil or growth media.

Maturity is the degree or level of completeness of composting. Maturity is not described by a single property and therefore maturity is best assessed by measuring two or more parameters of compost. Maturity is in part, affected by the relative stability of the material but also describes the impact of other compost chemical properties on plant development. Some immature composts may contain high amounts of free ammonia, certain organic acids or other water-soluble compounds which can limit seed germination and root development. All uses of compost require a mature product free of these potentially phytotoxic components.

Appropriate laboratory tests must be easy, rapid and reliable for evaluation of composts produced from all types of wastes with many different process methods. Many methods have been proposed and are practiced to describe stability and maturity. These include the carbon:nitrogen ratio (C:N); ammonium-N:nitrate-N ratio; paper chromatography; humic substances analysis; microbial biomass; cation exchange capacity (CEC); water extract analysis and; reheating tests. All of these approaches can provide additional information on material characteristics but have limitations when applied to the interpretation of the diversity of compost products. As example, an assumed ideal C:N ratio for a mature compost may be 10. However, certain raw and unstable waste materials (e.g. some manures) may have

low C:N ratios while, conversely an immature compost with a high 'ash' or low organic matter content could possible have a similarly low ratio.

Compost producers and users should realize that the presently accepted methods to evaluate stability and maturity may not completely or precisely address the most important concern, 'Is it appropriate for the particular end-use?' All of the test procedures described in this guide provide indirect interpretations for the potential impact on plant growth. In most cases these tests and determinations are performed on samples comprised of 100 percent compost. However, compost is used as an additive that may range from 30 to less than 1 percent of the total media or soil volume. In the absence of even more specific tests that evaluate the material based on a particular use, it is very important for the producer of compost to become more aware of the requirements for different end-use markets.

Section 2
THE CCQC MATURITY INDEX

A mature compost will exhibit characteristics that indicate completeness of the composting process and minimal potential for negative impacts on plant development. As maturity is not described by a single property, the maturity index, based on "passing" two or more specific tests will provide the greatest assurance to the producer and end-user. Test methods that are applicable are those which have demonstrable relevance to stability and maturity.

A Maturity Index characterization requires that the producer provide the C:N ratio of the finished product and reports at least one parameter from each of the following Group A and B lists. Compost samples must first pass the C:N ratio standard prior to consideration of results from tests in Group A and B. The results of Group A and B tests will determine compost to be very mature, mature or immature. No tests should be used to satisfy Group A and B requirements where interpretation has not been generally agreed upon.

These ratings are based on current standards established by experienced analytical specialists. However, at this time exact interpretation of a Maturity Index is not universally accepted by all commercial laboratories and may be subject to additional refinement in the future.

Carbon to Nitrogen (C:N) Ratio (Mandatory)

Compost must first have a Carbon to Nitrogen (C:N) ratio of less than or equal to 25 in order to be rated as acceptable prior to additional maturity rating from results of tests in Group A and B.

Group A (Perform one or more)

- Carbon Dioxide Evolution or Respiration
- Oxygen Demand
- Dewar Self Heating Test

Group B (Perform one or more)

- Ammonium:Nitrate Ratio
- Ammonia concentration
- Volatile Organic Acids concentration
- Plant test

The three rating categories the CCQC Compost Maturity Index, very mature, mature and immature relate to the following compost characteristics:

VERY MATURE	MATURE	IMMATURE
Well cured compost	Cured compost	Uncured compost
No continued decomposition	Odor production not likely	Odors likely
No odors	Limited toxicity potential	High toxicity potential
No potential toxicity	Minimal impacts on soil N	Significant impact on soil N

Section 3
MATURITY INDEX METHODS

Carbon TO Nitrogen Ratio

ORGANIC CARBON

Determination of organic carbon provides a direct estimate of the biologically degradable carbon (C) in the compost. During composting carbon is transformed into more complex organic compounds such as humus and mineralized and lost as carbon dioxide (CO_2). The total organic C in compost includes forms of organic matter at different stages of degradation, some resistant to further decomposition and some remaining biologically active. A number of laboratory procedures can provide accurate and precise measures of organic C and the following are acceptable.

Combustion with CO_2 Analysis. A dried sample (often quite small) is ground to a powder, then burned at a very high temperature. The CO_2 produced is blown in an oxygen-rich air stream into a detector to measure the total amount of CO_2, and therefore organic carbon, released from sample combustion.

Modified Mebius Procedure. A dried sample is lightly ground and then is 'chemically' burned or oxidized by concentrated sulfuric acid in the presence of the reactant potassium dichromate. The mixture is then heated sufficiently to cause the organic carbon in the sample to completely react with a portion of the dichromate reactant. The amount of organic carbon in the original sample is determined by further reaction of this mixture with ferrous sulfate.

ORGANIC MATTER

Determination of organic matter is a more routinely applied laboratory procedure for composts and provides an estimate of all substances containing organic carbon. Organic matter (OM) composition and content declines during composting as described for organic carbon. However a measurement of organic matter is only an indirect estimate of organic carbon. Many laboratories will use a 'correction' factor to estimate a value for organic carbon, which may not always provide an accurate and precise estimate. The following is the most common procedure for measuring organic matter in composts.

Loss-On-Ignition (LOI) Method. A relatively large dry sample (10 grams) which has been passed through at most a 10-mm (0.4 inch) screen is burned at a high temperature. The ash that remains is weighed and organic matter determined by the difference in weight between the original and ignited sample.

Limitations

Inert plastic materials, particularly hard plastics, remaining in a sample may be measured as organic carbon or organic matter by the methods described above. Therefore you should be certain that your laboratory attempts to remove as many plastic contaminants as practical prior to analysis.

Compost that is known to contain high amounts of carbonates (e.g. from additions of amendments like dolomite or lime) may increase organic carbon determinations due to the release of CO_2 during sample combustion in the CO_2 detection method. Samples must be pre-treated (leached with acid) prior to analysis by the combustion method.

As mentioned previously, many laboratories estimate organic carbon from determinations of organic matter by the LOI method. However, there is not a uniform agreement as to the appropriate 'correction' factor for this conversion. Typically, organic carbon may be calculated by multiplying organic matter content by a 'correction' factor ranging between 0.5 to 0.58.

TOTAL NITROGEN / ORGANIC NITROGEN

The composition of raw starting materials, as well as, process conditions will affect the total nitrogen (N) content of compost. The organic nitrogen in compost is that bound only in organic matter, while the total nitrogen content is typically defined as the sum of organic and inorganic forms (ammonium-, nitrite-, and nitrate-N). The organic N content of compost can be significantly lower than the total N content and, therefore the C:N ratio often must be calculated from the total N content of the material. There are two basic approaches that are commonly used by laboratories.

Kjeldahl Nitrogen (Wet Combustion) Method. Typically a small, dried and ground sample (0.25 grams) is mixed with concentrated sulfuric acid and a high concentration of a salt like potassium sulfate (see Limitations below). This mixture is then heated or digested at a high temperature for up to 2 hours. This digestion decomposes all organic compounds and releases the N as ammonium. The resulting ammonium-N concentration is measured (see ammonium-N method). This method only measures organic- plus ammonium-N in the sample. When the nitrate-/nitrite-N level in compost is thought or known to be high (greater than 500 ppm), then this method will not be provide an accurate measure of total N.
A modification of this Kjeldahl method, includes what is known as a reduction step, which converts the nitrite- and nitrate-N into ammonium. The resulting value is the total N content which can be used to calculate the C:N ratio.

Dry Combustion (Dumas) Method. Typically a very small, dried and ground sample (less than 0.1 grams) is burned at a high temperature in a pure CO_2 air stream. All of the N in a typical compost sample is converted to an oxidized gas, then to N_2 gas, which is measured by a suitable detector. The concentration of N_2 gas is a direct measure of total N.

Limitations

Under certain conditions, sample handling may introduce errors in the analysis of total N. Samples that contain a significant portion of total N as ammonia-N (typically immature composts) may have significant losses of that N, due to volatilization of that N during drying and grinding. Thus the resulting analysis of total N may be in error. Mature compost will not have such high levels of ammonia (see Group B ammonia limits) and, therefore the loss of N during drying may be considered insignificant.

Group A Indices

The procedures required for each of the listed procedures are accepted as measures of compost stability. At this time the most widely used and commonly accepted methods for determining compost stability are based on respirometry. Respirometry is the measurement of carbon dioxide evolved or oxygen consumed by microorganisms within the material, which provides an estimate of potential biological activity. Higher rates of carbon dioxide release or oxygen consumption will reflect less stable composts.

Laboratory methods will typically measure either oxygen uptake or reduction or carbon dioxide generation as measures of biological activity or decomposition stage in a compost sample. A stable compost is not biologically inert, as the presence of microorganisms is dependent upon continued availability of biodegradable organic matter. However, in comparison to early stages of composting the decomposition rate should be dramatically lower. Strict application and interpretation of a stability test may be unreliable if other factors that may influence microbial activity (e.g. salinity, toxic inorganic or organic compounds) are not considered. Additionally, any respiration-based test must be based on the organic matter content, rather than simply the total weight of the material sample.

Methods for Group A

Currently there are a number of tests available to determine compost stability. Some have been submitted for publication in the first edition of Test Methods for the Examination of Composting and Compost (TMECC) by the U.S. Composting Council (USCC), while commercial laboratories have developed others. They include:

- Oxygen Uptake Rate
- Specific Oxygen Uptake Rate

- Carbon Dioxide Evolution Rate
- Respiration Rate
- Self-Heating Test
- Solvita® Test

Each of these tests is interpreted by comparison to a stability index value specific to each method (Table 1). Although oxygen consumption and carbon dioxide generation or evolution are related, the measurements are not consistently equivalent. Generally the measurement of oxygen consumption requires more sophistication, time and quality control, in comparison to the more simple and often more precise measurement of carbon dioxide evolution. The Dewar Self-Heating Test integrates a number of factors and provides an evaluation of compost that may correlate well to field observations of the composting process. In comparison to the methods based on respirometry, the method is relatively simple and provides data that is easy to understand, as units of heat. The Solvita® test is a package system that estimates respiration and ammonia by a color forming chemical reaction.

Oxygen Uptake Rate (OUR Test)
The changes in oxygen concentration with time in the air space of a closed container containing a moist compost sample of known volume and weight, at known temperature and pressure is monitored. All samples have large pieces of inerts removed. Samples are adjusted to 40-50 percent moisture, then samples are pre-incubated in bags placed in a constant temperature environment at 37–§ C and 100 percent humidity for a minimum of 24 hours. The sample is then added to a container that is sealed with appropriate monitoring equipment to allow measurement of oxygen consumption every minute for at least 90 minutes.

The results are calculated as oxygen uptake per unit of total sample solids (see Section 5, Definitions).

Specific Oxygen Uptake Rate (SOUR Test)
The method is identical as for the OUR Test, however the results are calculated as oxygen uptake per unit of biodegradable volatile solids (see Section 5, Definitions).

Carbon Dioxide Evolution Rate
The amount of carbon dioxide released with time in the air space of a closed container containing a moist compost sample of known volume, weight, at known temperature and pressure is monitored. All samples have large pieces of inerts removed. Samples are adjusted to approximately 50 percent moisture, then samples are pre-incubated in bags placed in a chamber at 37§ C and 100% humidity for 3 days. The sample is then added to a container that

is sealed with appropriate monitoring equipment to allow daily measurement of carbon dioxide evolved for a 4-day period.

The results are calculated as carbon dioxide evolved per unit of total sample solids and total biodegradable volatile solids.

Respiration Rate (Soil Control Laboratory)
The basic elements of this respiration test are similar to the other CO_2 evolution rate tests with a few modifications. Following removal of large particles (>4 mm) and inerts, the material is mixed with saturated sand (about 4:1 ratio) to adjust moisture and ensure uniform release of carbon dioxide. Before a three-day incubation at 37° C, the sample receives additions of a Hoagland's nutrient solution and mesophillic microbial inoculant to remove any biological limitation. After three days several sub-samples are aerated then are incubated for one hour at 37 °C and the resulting carbon dioxide concentration in the air space of the container is determined.

The results are calculated as carbon dioxide evolution per unit of volatile solids.

Respiration Rate (Woods End Laboratory)
Methods are similar to those used for the carbon dioxide evolution method (see above), however the incubation period is only one day rather than three.

Dewar Self-Heating
The Self-Heating test uses a standardized steel container that holds approximately 2 liters (2.1 quarts) of compost. The compost sample moisture content may need to be adjusted prior to incubation. A maximum-minimum thermometer is then inserted to about 5 cm (2 inches) of the bottom of the container. The container is placed in area that will maintain temperatures between 18 – 22 °C for a period of at least 5 days and no more than 10. The temperature of the compost sample is recorded daily.

The results are calculated as maximum temperature rise during the test period.

Solvita® Test (Woods End Laboratory)
The Solvita® Test is a color-coded test procedure that determines a maturity index based on a two-tiered test system using respirometry and ammonia gas emission. The moisture content of a composite sample is determined qualitatively by visual and 'feel' criteria. Moisture adjustments or drying are used prior to running the test. A known volume (adjusted by tapping or tamping) of the sub-sample is then added to a test jar. If sample has been adjusted (adding water or drying) then it is allowed to incubate or equilibrate for 16 to

24 hours prior to the test. Following the equilibration period a specially treated 'paddle' is placed in the test jar and after 4 hours the color developed on the gel surface of the 'paddle' is visually compared to a coded color chart. Two gel results indicate CO_2 and ammonia (NH_3) concentrations. As this test method estimates respiration and NH_3, it may provide simultaneous data for maturity Group A and Group B parameters.

Limitations

Compost samples that have a moisture content below 30-35 percent may be biologically dormant; thus respiration rates will be artificially low without additional water. Therefore a standard adjusted moisture content must be applied for all samples. Previously dried or cold stored samples may support uncharacteristically high biological activity (respiration) following moisture adjustment or increased temperature. Therefore a pre-incubation or equilibration of each sample must be employed to assure accurate measurements of respiration activity.

The length of pre-conditioning or pre-incubation step may not be uniform between the methods given in this section or different laboratories and may range from 24 hours to 3 days. Thus it is possible that the results from an identical sample analyzed following different pre-incubation times may lead to different and possibly erroneous interpretations.

Improperly prepared samples that are overly moist or tightly packed in a sealed container and shipped at temperatures above about 40° F may arrive to a laboratory in anaerobic condition. These samples may not be representative of the source material. Samples of actively composting material, particularly from thermophillic zones will largely contain microorganisms which are not active at lower, mesophillic (37° C or 98° F) temperature conditions used in respiration based methods described here. Compost from heat or moisture (lack of) damaged windrows may falsely test as stable due to the lack of viable microbial populations. Most of the respirometry-based and Dewar Self-Heating procedures may provide erroneous determinations when compost with the above characteristics are tested. Compost samples collected from active piles must be re-equilibrated at room temperature before producing reliable results.

The Soil Control Laboratory method for measuring potential respiration, which attempts to remove nutrient and microbial limitations, may successfully overcome the limitations due to anaerobic condition, samples from thermophilic zones, or heat damage

The Solvita test measures compost respiration rate and ammonia liberated from a standardized volume of sample, as opposed to weight (see other respirometry methods). A number of factors may interfere with reliable reaction of the CO_2 gel. High levels of volatile

organic acids (VOA) will interfere positively with the Solvita gel, thereby increasing the apparent respiration by as much as one [1] color change. High levels of ammonia (NH_3) in compost may lower the CO_2-evolution rate due to toxic effect on microbial activity, but errors can be corrected by reference to the ammonia gel reading. In certain cases where the compost sample is anaerobic, other gaseous by-products can be produced resulting in an off-coloring of the Solvita gel. If the test is run at temperatures outside of the range (20-25° C), the results should be read at more or less than four hours. There is a chance for greater error in comparison to laboratory methods, as the test is designed for 'field' use by non-technical personnel.

Interpretation

Table 3-1 provides the appropriate interpretative values for very mature, mature and immature composts based on each of the Group A tests. Different values for methods based on respirometry reflect differences in the method of calculation (units) or conditions of the test.

Table 3-1
Maturity indices for Group A (stability) methods

Method	Units	Rating		
		Very Mature	Mature	Immature
OUR Test	O_2 / unit TS / hr	< 0.4	0.4 - 1.3	> 1.3
SOUR Test	O_2 / unit BVS / hr	< 0.5	0.5 - 1.5	> 1.5
CO_2 Test	C / unit VS / day	< 2	2 - 8	>
SCL CO_2	C / unit VS / day	< 2	2 - 8	> 8
WERL CO_2	C / unit VS / day	< 5	5 - 14	< 14
Dewar	Temp. rise (°C)	< 10	10 - 20	> 20
Solvita®	Index value	7 - 8	5 - 6	< 5

SCL = Soil Control Laboratory

WERL = Woods End Research Laboratory

Group B Indices

The presence of compounds toxic to plants (phytotoxic) is perhaps the most common problem associated with the utilization of immature composts. Immature composts may contain or generate ammonia and/or inorganic or organic compounds that may reduce seed germination, root development and function. During the early stages of composting significant quantities of ammonia and a wide variety of water-soluble and/or volatile organic acids (e.g. acetic acid, amines) are generated. However, with time in a typical aerobic process,

these materials will either be volatilized to the atmosphere or undergo further biologically mediated conversion to less soluble and/or phytotoxic compounds. Even mature composts may be phytotoxic due to the level or type of soluble salts.

During early stages of composting very little if any nitrate-N is formed. As the rapid decomposition or thermophillic stage is passed, the mesophillic microorganisms that convert organic N to ammonium- and nitrate-N begin to flourish. The appearance of significant quantities (greater than 50 ppm) of nitrate-N can be an indicator of maturing compost. With further maturation the nitrate-N levels in compost will begin to exceed that of ammonium-N. Therefore, determination of an ammonium- to nitrate-N ratio provides a useful parameter to assess the degree of maturity. However, when the sum of ammonium- and nitrate-N is less than 250 ppm on a dry weight basis, then this ratio may not provide a reliable measure of maturity.

A direct assessment of phytotoxicity can be made by growing plants in mixtures of compost, soil and/or other inorganic or organic media, or by germination and root elongation measurements (growth screening) after exposure of seeds to growth media containing compost or water extracts of compost. By nature of the definition, a plant assay may indicate either none or any one or more of these factors. The test results are dependent on preparation of the media especially in regards to concentration. Thus, any test method used to evaluate potential phytotoxicity should reference the exact plant method (see Plant Test) and concentration of compost used.

Indirect assessments can involve determination of specific organic compounds or classes of organic compounds. Some researchers have proposed that simply determining the total water-soluble organic matter in composts may provide evidence of maturity. These direct methods will also assess the impact of total or specific soluble salt levels on plant development. However, these methods have not been sufficiently tested and evaluated at this time.

Methods for Group B

The following recommended tests have been selected to complete the assessment of compost maturity. The procedures are largely consistent with those submitted for publication in the first edition of Test Methods for the Examination of Composting and Compost (TMECC) by the U.S. Composting Council (USCC), and are in general use by many commercial laboratories. They include:

- Ammonium:Nitrate Ratio
- Ammonia Concentration

- Volatile Organic/Fatty Acids Concentration
- Plant test

AMMONIUM-NITROGEN (NH_4-N)

Nitrate-Nitrogen (NO_3-N)

Typically, a sample at as-is-moisture and which passed a 6 mm screen is added to water (occasionally for NO_3-N), but more often a concentrated salt solution. The container is then shaken to extract both nitrogen forms. After extraction, filtration and, if necessary, color removal, a small liquid sample is reacted with appropriate chemicals, which develop a color in response to the concentration of ammonium- or nitrate-N. Some methods for NO_3-N analysis may also determine the nitrite-N (NO_2-N) concentration in the sample

Ammonia-N (NH_3-N)

Tests for ammonia may involve incubation of a sample (up to 25 grams) at as-is-moisture in a closed container to measure release of ammonia gas for a set period. Ammonia gas can be captured in acid solution 'traps' placed in sealed containers, that convert the gas to ammonium for subsequent analysis. The 'headspace' air in such a closed incubation container can also be sampled with detection of ammonia done with a gas chromatograph. The Solvita® test allows for a determination of ammonia concurrently with CO_2 (see Group A methods).

Volatile Organic or Fatty Acids Concentration (VOA or VFAs)

Typically a sample (5 grams) at as-is moisture and which passed a 6-mm screen is added to water buffered at pH 7.0. The container is then shaken to extract the acids. After the extraction a small volume sample of the solution is removed, then this liquid may be further treated to remove interfering compounds or color prior to analysis. The sample is then analyzed for individual acid types with a gas chromatograph.

Plant Test Methods

The use of a plant type in an actual growth trial employing compost at a defined ratio. Plant tests are designed to demonstrate efficacy of compost for a specific usage and should generally not be extrapolated to other different conditions. Most often tests use cress, cucumber, wheat, barley, or radish seed, all which have varying tolerances to soluble salts and other potentially toxic organic substances in compost. In some cases a potential end-user may prefer to specify a different test species which may more directly relate to their intended use.

Germination and Root Elongation. Water (up to 200 ml or approx. 6.8 oz.) is added to a large as-is sample (up to 400 grams) of compost. After a short time the water is filtered. A series of solutions at different strengths are prepared (typically undiluted, 3 times, 10 times diluted). Seeds are placed in these water extracts of compost and evaluated for germination percentage and root growth after two or three days (depending on the seeds used).

Direct Seeding 'Quick' Test. Seeds are planted in a blend of 50 percent compost and 50 percent vermiculite, watered with distilled water, and placed in a stable temperature environment (approximately 80° F). Emergence and growth are evaluated after 14 days and compared to growth of seeds planted in 100 percent potting soil and 100 percent vermiculite.

Germination and Root Elongation 'Quick' Test. This test is similar to the first plant test, except a compost extract of approximately two parts water to one part compost is prepared. Seeds are exposed to the single strength extract, and after two to three days are compared to germination and growth of seeds exposed to distilled water.

Limitations

Inorganic N. If compost samples are dried or stored, the ammonium- and/or nitrate-N content may change due to microbial activity or volatilization. Analysis for ammonia requires strict attention to proper sample handling as this gaseous form of N can easily volatilize from a sample. Analysis of ammonia with acid traps may be subject to small errors due to capture of other volatile compounds containing N.

VOAs or VFAs. The methods are time-consuming and can be expensive.

Plant tests. The tests do not determine the exact cause of growth or germination reduction, by either ammonia, salts, organic acids, high or low pH. Some plant species are more tolerant of high salt concentrations than others, and therefore may not predict performance for low tolerance species. Reproducibility of results in direct seeding tests may be poor if there is poor quality control on potting soil preparation. Compost samples should not be blended or diluted with other materials prior to use in any of these tests.

Interpretation
Table 3-2 provides the appropriate interpretative values for very mature, mature and immature composts based on each of the Group B tests.

Table 3-2
Maturity Indices for Group B

Method	Units	Rating		
		Very Mature	Mature	Immature
NH_4- : NO_3-N Ratio*	No units	< 0.5	0.5 - 3	> 3
Total NH_3-N	ppm, dry basis	< 100	100 – 500	> 500
VOA	ppm, dry basis	< 200	200 - 1000	> 1000
Seed Germination	% of control**	> 90	80 - 90	< 80
Plant Trials	% of control	> 90	80 - 90	< 80

* If both levels of NH_4 or NO_3 are low in compost (i.e. less than 250 ppm) the ratio is a less reliable measure of maturity.

**Control refers to water only or potting soil treatment.

Section 4
BEST USES OF COMPOSTS BASED ON MATURITY

Table 4-1 gives very general use guidelines for composts according to the three maturity index classes. Potential users should be aware that maturity alone does not determine the appropriate use for a compost. Please refer to the nutrient content, soluble salts, ammonia, and pH for further guidance for selection of appropriate material for any desired use.

Table 4-1.
Best Use of Composts Based on Maturity Index Rating

Rating	Potential Uses
VERY MATURE	Soil and peat-based container plant mixes Alternative topsoil blends, turf top-dressing.
MATURE	General field use [pastures, hay], vineyards Row crops, substitute for low analysis organic fertilizers in some cases.
IMMATURE	Land application to fallow soil. Feedstock for compost.

Additional information on compost use may be found in The Field Guide to Compost Use (United States Composting Council – www.compostingcouncil.org). Compost Maturity and/or the CCQC Maturity Index should never be the sole indicator for determining compost end use. Compost application instructions should consider multiple compost analytical parameters, (e.g., pH, soluble salts, sieve size, nutrient content, metals content, pathogens, Ag Index, etc.) and perhaps most importantly the intended use of the compost and the expected performance.

Section 5
DEFINITIONS

Biodegradable volatile solids: The biodegradable portion of total solids that volatilizes to carbon dioxide and other gasses when a compost or feedstock is combusted at 500±50°C in the presence of excess air.

Germination: The extent of sprouting of a test seed as in cress or lettuce in a sample or extract of compost. The test results are dependent on preparation of the media especially in regards to concentration. Any test of germination should report the plant method and concentration of compost or extract used.

Loss-on-ignition organic matter: The biodegradable portion of total solids that volatilizes to carbon dioxide and other gasses when a compost or feedstock is combusted at 400±20°C in the presence of excess air.

Maturity Index: An evaluation procedure to describe the degree of decomposition and completeness of a compost process. The maturity Index relies on any two or more test methods performed concurrently on the same sample. Test methods that are applicable are those which have demonstrable relevance to stability and maturity. For a Maturity Index, tests should include at least one parameter each from the A list and the B list (see Maturity Index Test Methods).

Phytotoxicity: A condition or quality of compost that negatively influences plant growth. Similar to maturity, phytotoxicity is not a single property of compost. Factors such as salt, volatile organic acids, or ammonia all play a role in determining phytotoxicity.

Total solids: The solid fraction (percentage, wet basis) of a compost or feedstock that does not evaporate upon heating to 70±5°C; this fraction consists of fixed solids, biodegradable volatile solids, and volatile solids not readily biodegradable.

Volatile fatty acids: These compounds are formed during decomposition of organic material and are a large group of weak organic acids which evaporate easily at room temperature. They can be phytotoxic at high concentrations. These organic acids (VFAs or VOAs) are a source of odors during composting, but will largely be degraded to CO_2 and water under aerobic conditions and with adequate curing.

Section 6
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Appendix A
CCQC COMPOST MATURITY INDEX IN THE TMECC

The following is the text from "Test Methods for the Examination of Compost and Composting" developed by the US Composting Council, to be published through the General Printing Office by USDA. The TMECC is a living, peer-reviewed document, please check www.compostingcouncil.com/tmecc/ for periodic updates.

Method 05.02-G CCQC Maturity Index—The California Compost Quality Council (CCQC) Maturity Index is assessed by measuring at least three [3] parameters of compost. Parameters are selected from a list within two groups comprising distinctly different types of tests, i.e., stability and indicators of maturity (Table 05.02-G2).

Interpretation is based on the recognition that distinctly different traits may characterize compost immaturity. Immature composts can contain high concentrations of free ammonia, volatile fatty acids or other water-soluble compounds that may inhibit seed germination and root and seedling development.

Immature and poorly stabilized composts can pose problems during storage or shipping, and use. The material may become anaerobic, odorous, and develop toxic compounds. Active decomposition of the material after application to soil or addition to growth media can impair plant growth by reducing root-available oxygen, plant-available nitrogen, or through release of phytotoxic compounds into the root zone.

Many compost applications require a stable to very stable compost product, i.e., a product that will not compete with plants for required nutrients or availability for oxygen in the soil or growth media.

Interference and Limitations

Method 05.02-A Carbon to Nitrogen Ratio—When measuring C:N of either feedstock or finished product, the ratio must be that of % total organic carbon to % total nitrogen, i.e., includes total organic plus inorganic nitrogen.

Total Kjeldahl Nitrogen (TKN) alone is not always an adequate indicator of nitrogen status, although it includes organic nitrogen and ammonia nitrogen, it does not include nitrate nitrogen which may be present at increasing quantities in stable compost.

Refer to Method 04.02 (Nitrogen) and Method 04.01 (Organic Carbon) for specific details.

Method 05.02-B Carbon to Phosphorus Ratio—Refer to Method 04.03 (Phosphorus) and Method 05.01 (Organic Carbon) for specific details.

Method 05.02-C Ammonium to Nitrate Ratio— The NH_4-N:NO_3-N ratio has little value and should not be considered a valid Group B parameter to establish a Compost Maturity Index Rating for composts with very low concentrations of both NH_4–N and NO_3–N (including NO_2–N), i.e., their sum is less than approximately 75 to 100 mg kg^{-1} dw. Refer to Method 05.02-G CCQC Maturity Index for additional maturity indices.

Method 05.08-D Carbon to Sulfur Ratio—Refer to Method 04.05-S. Sulfur and Method 05.01 Organic Carbon for description.

Method 05.02-F Agricultural Index—Proper application of the AgIndex requires optimum edaphic conditions of target soil and the compost in question, (e.g., optimal compost and soil texture, water holding capacity, porosity, aeration, bulk density, pH, etc.). Factors that commonly limit crop growth after compost application include: 1) high sodium or chloride levels; 2) biologically unstable material (rapid oxygen uptake and carbon dioxide evolution); and 3) the presence of toxins generally associated with anaerobic conditions or immature compost products. The AgIndex is used to diminish the probability that sodium and chloride or deficient nutrients become the limiting factor.

Method 05.02-G CCQC Maturity Index—Anticipate continued refinement of the numerical thresholds presented in Tables 05.02-G3 and 05.02-G4.

A Maturity Index should not be the sole indicator for determining compost use. Use instructions should consider multiple compost analytical parameters, (e.g., pH, soluble salts, sieve size, nutrient content, AgIndex, etc.).

05.02-G CCQC MATURITY INDEX

LOOK—Interference and Limitations, and Sampling Handling issues are presented as part of the introduction to this section.

SUBMITTED BY—The California Compost Quality Council (CCQC) Stability/Maturity Oversight Committee[1].

[1] The CCQC Maturity Index was developed under a contract with the California Integrated Waste Management Board. CIWMB Project Manager - Mike Leaon; and CCQC Project Manager - Matthew Cotton, Integrated Waste Management Consulting, Nevada City, California. The Maturity Index evolved from the CCQC Laboratory Practices Committee Chaired by Dr. Marc Buchanan, Buchanan Associates, Scotts Valley, California. Committee members included: William F. Brinton, Woods End Laboratories, Mt. Vernon, Maine; Frank Shields, Soil Control Laboratory, Watsonville, California; James West, Soil and Plant Laboratory, Santa Clara California; and Wayne H. Thompson, Edaphos International, Houston, TX.

Interpretations for Method G
Maturity Rating—Compost is tested and classified as "very mature, mature, or immature" according to the Compost Maturity Index.

The compost maturity index is implemented using a two-tier decision process as illustrated in Figure 05.02-G1.

Figure 05.02-G1. Compost Maturity Assessment Process

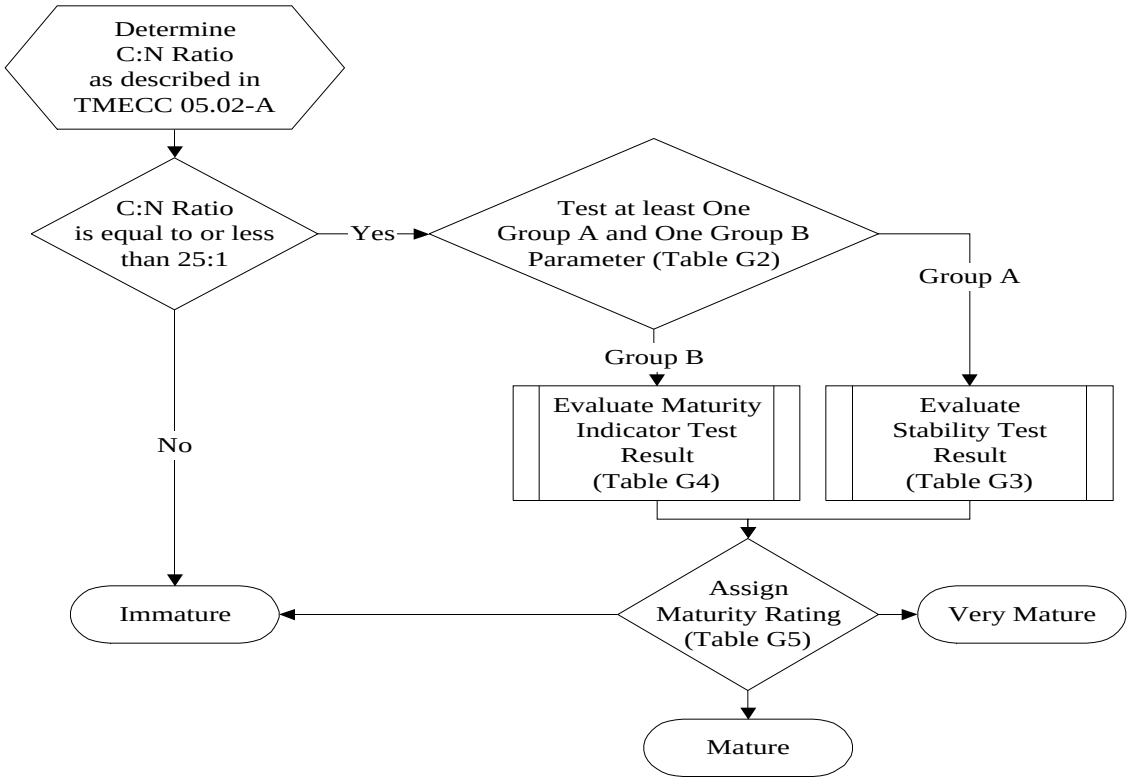


Table 05.02-G1
Compost Maturity Index

VERY MATURE	MATURE	IMMATURE
Well cured compost	Cured compost	Uncured or raw compost
No continued decomposition	Odor production not likely	Odor production likely
No toxicity potential	Limited toxicity potential	High toxicity potential
No impact on plant-available soil nitrogen	Minimal impact on plant-available soil nitrogen	Significant impact on plant-available soil nitrogen

Table 05.02-G2
Compost Maturity Index Parameters

Carbon Nitrogen Ratio (C:N, TMECC 05.02-A)	
Group A (Stability)	Group B (Maturity)
Respirometry Tests (TMECC 05.08): ▪ Specific Oxygen Uptake Rate (TMECC 05.08-A); ▪ Carbon Dioxide Evolution Rate (TMECC 05.08-B); ▪ Dewar Self-Heating Test (TMECC 05.08-D); ▪ Solvita CO_2 (TMECC 05.08-E); and/or ▪ Biologically Available Carbon (TMECC 05.08-F)	Ammonium (TMECC 04.02-C); NH_4-N:NO_3-N Ratio[2] (TMECC 05.02-C); Biological Assays (TMECC 05.05): ▪ Emergence and Seedling Vigor ▪ In-Vitro Germination and Root Elongation, or ▪ Earthworm Bioassay: The Minnesota "Z"-Test; Solvita NH_3 (TMECC 05.08-E); and/or Volatile Fatty Acids (TMECC 05.10-A)

CAUTION !—Anticipate continued refinement of the numerical thresholds presented in Tables 05.02-G3 and 05.02-G4. A Maturity Index should never be the sole indicator for determining compost end use. Compost application instructions should consider multiple compost analytical parameters, (e.g., pH, soluble salts, sieve size, nutrient content, metals content, pathogens, Ag Index, etc.).

Compost Stability—At least one respirometry method is selected and the test outcome is evaluated according to the thresholds presented in Table 05.02-G3.

[2] For composts with very low concentrations of both NH_4–N and NO_3–N (including NO_2–N), i.e., their sum is less than approximately 75 to 100 mg/kg dw, the NH_4-N:NO_3-N ratio has little value and should not be considered a valid Group B parameter to establish a Compost Maturity Index Rating.

Table 05.02-G3
Stability Thresholds Using Respirometry

	Rating		
Group A (Stability)	Very Stable	Stable	Less Stable
Specific Oxygen Uptake Rate (mg O_2 per g OM per d)	< 12	12 – 36	> 36
Carbon Dioxide Evolution Rate (mg CO_2-C per g OM per d)	< 2	2 – 8	> 8
Dewar Self-Heating Test (Dewar Index)	V	IV	III, II, or I
Headspace Carbon Dioxide (color-code for Solvita CO_2)	7 – 8	5 – 6	1 – 4
Biologically Available Carbon (mg CO_2-C per g OC per d)	< 2	2 – 4	> 4

ADAPTED FROM—TMECC Table 05.08-1 Compost Stability Index.

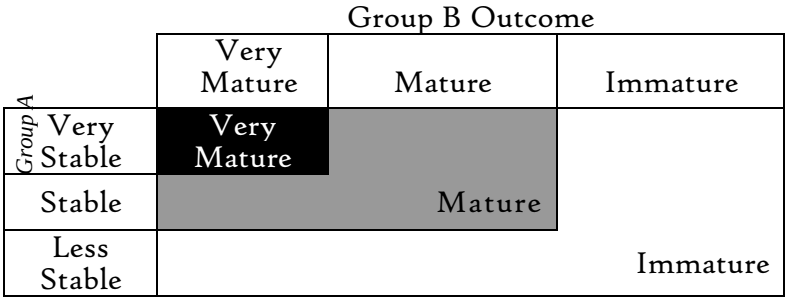
Maturity Indicators—At least one maturity indicator is selected and the test outcome is evaluated according to the thresholds presented Table 05.02-G4.

Maturity Assessment—A compost is assigned a maturity rating of immature, mature, or very mature, pending the outcome of up to three [3] parameters analyses. The compost C:N ratio is first evaluated: a compost with a C:N ratio greater than 25:1 would be classified as immature compost; no further testing would be necessary needed for the maturity classification. If the C:N ratio is equal to or less than 25:1, then the compost must be evaluated for both stability using one of the parameters listed in Group A (Table 05.02-G3), and for maturity using one of the indicators presented in Group B (Table 05.02-G4). All possible maturity assessment outcomes are presented in Figure 05.02-G2.

Table 05.02-G4
Maturity Thresholds for Maturity Indicators

	Rating		
Group B (Maturity Indicator)	Very Mature	Mature	Immature
Ammonium, (mg kg^{-1} dw)	< 75	75 - 500	> 500
Ammonium:Nitrate Ratio[3], (unitless ratio)	< 0.5	0.5 – 3.0	> 3.0
Seedling Emergence, (% of control), AND	> 90 and	80 – 90 and	< 80 and
Seedling Vigor, (% of control)	> 95	85 – 95	< 85
In-Vitro Germination and Root Elongation , (% of control)	> 90	80 – 90	< 80
Earthworm Bioassay: The Minnesota "Z"-Test (% weight gain)	< 20	20 – 40	> 40
Ammonia, (color-code for Solvita NH_3)	5	4	3 – 1
Volatile Fatty Acids, (mmoles g^{-1} dw)	< 200	200 – 1,000	> 1,000

Figure 05.02-G2. Maturity Assessment Matrix



The Maturity Assessment Matrix is applied when the C:N Ratio is equal to or less than 25:1.

[3] NO_3-N represents a sum of both nitrite and nitrate forms of nitrogen.