INTERPRETATION OF WASTE & COMPOST TESTS

Woods End Research Laboratory

SOLIDS / MOISTURE: There is no absolute moisture level which is ideal for manure, composts or waste products. Ideal moisture is relative to processing goals and to the sample's water holding capacity (WHC). The Woods End report gives WHC% on a dry and as is basis. Optimal biological activity in compost occurs at 60 – 80% saturation of WHC. The "squeeze-test" for moisture when done carefully reflects accurately the relative relationship of water to the sample's water holding capacity. Thus, a low organic matter material (i.e. 30% OM), is adequately wet at 30 to 40% moisture. A high organic sample, typical of a fresh compost mix, will require from 45 to 65% to be ideally moistened.

Water holding capacity diminishes during biodegradation, due to loss of organic content, and thus the ideal level of moisture will likewise diminish, often significantly.

pH and Carbonates: The pH of any material must be interpreted in view of the origin and the intended use. Lime-treated wastes normally have moderately to very high pH. In conjunction with elevated pH, free lime (carbonates) may be present and are reported on a scale of low, med and high. The significance of pH and presence of carbonates is frequently underestimated. Ideally, the pH of any product, particularly compost, should be neutral to slightly acid (6.0 – 7.5) and efforts should be made to control it if it exceeds about 8.5. Lowering a high pH will help lower ammonia volatilization and reduce odors, as it will also favor a balanced microbial population. In potting soils, pH adjustment is important for reasons of healthy plant growth.

ORGANIC MATTER / Volatile Solids : Organic matter is reported in terms of total OM (weight loss on ignition minus total nitrogen). Volatile solids are normally simply reported from weight loss. There is no absolute level of organic matter which is ideal, rather the quantities must be viewed in relation to the age of a material, its nitrogen content, and its intended use. It is useful for purposes of composting to report the initial OM and contrast it with OM determined periodically at later points. This gives an idea of the extent of decomposition. Organic matter may be lower than expected because of incorporation of soil or sand. The OM test forms the basis for determining the sample's C:N ratio (see later). Conversion to organic carbon is based on the factor OM x 0.54 and is based on actual correlation analyses.

NITROGEN: total-Kjeldahl-N, organic-N, ammonium, nitrate, nitrite: The quantity and form of nitrogen present in manure or compost is important in shaping the material's quality. In the Woods End test, you will notice several entries for nitrogen. For mature compost, it is desirable that most of the nitrogen be organic, and that the ammonia fraction be small. In advanced composting we expect to see nitrate generation. If this is not evident by test, it may indicate insufficient oxygen causing gaseous loss by denitrification, a high pH causing inhibition of nitrifying microorganisms, or other factors which are generally discussed. We report the percent of total nitrogen which is found to be immediately soluble, useful where fertilization is concerned. Also reported is the amount of nitrogen which is immediately volatile as ammonia vapor, i.e. which is subject to loss if the material is surface spread, or otherwise mistreated. Values exceeding 15% are considered to be high. Volatility of ammonia is determined by pH, so if you have a medium to low pH you need not worry about the ammonia losses. Concerning nitrogen release over the season, one should estimate this by considering the climate and the sample's intrinsic rate of decomposition (for example, as determined in our respiration test). Using either one of the two factors alone to judge the amount of nitrogen release may prove misleading. Our research indicates that nitrogen release from similar manures applied to the same soil may vary from as little as 20% up to 75% of total-N.

CARBON:NITROGEN RATIO: It is customary to use C:N figures to assess the rate of decomposition of compost mixtures. If we know that a material has undergone composting, C:N ratios may accurately reflect when ripeness has been reached. However, caution is necessary before taking any actions based on the C:N figures alone. One must consider that not all the total carbon is actually available for microbial use. Or, if nitrogen is lost, C:N ratios may go up not down during late stages of composting. C:N values must be weighed against observed decomposition traits. Compost may be considered finished anywhere around a C:N of 17 or less, unless coarse woody material remains.

MINERALS- Phosphorus, Potassium, Calcium, Magnesium, Sodium, Chloride, Sulfate: These minerals are reported in their total rather than available forms. The amounts actually available will be an unknown but generally significant fraction. In the case of potassium and sodium experience has shown that more than 80% of the total is likely to be immediately available, whereas with phosphorus, calcium and magnesium the availability will range from as little as 25% up to about 75%. More P, Ca and Mg are available under acidic soil conditions. An optional test can be performed to determine the official amount of available P. For estimating the amount of nutrients available the first season, we suggest you take 50% of the P, Ca and Mg figures and 85% of the K and Na figures.

SALINITY, ELECTRICAL CONDUCTIVITY: Soluble salt level (salinity) in a sample is estimated based on measurement of the electrical conductivity of a saturated paste. Components contributing most to salinity are sodium, potassium, chloride, nitrate, sulfate, ammonia, and VOA. Low levels are expected for potting composts (<2) whereas in the case of fresh composts the values may be acceptable in the range of from 3 –10, and higher, depending on use. Low values will indicate a lack of available minerals, while high values indicating a large amount of soluble minerals may inhibit biological activity or cause problems with land application if large quantities of the material are used. The units of conductivity in the report is the traditional mmhos/cm, which is equivalent to dS/m or dS m^{-1}.

Evaluation of SALINITY in Compost Tests, mmhos/ cm				
< 1.0	1 - 2	2 - 5	5 - 10	> 10
V - LOW may be used as direct substitute for soils	M - LOW topsoil substitute, container media	MEDIUM dilute 2- to 5-fold for most applications	M - HIGH dilute 3- to 10-fold for most applications	V - HIGH use only at low application rates

INERT CONTENT: Materials that do not contribute to compost activity are excluded from all analyses (except fresh density --- see below) and shown in the report as *inert of oversized matter.* This category includes man-mades such as metals, plastic, glass, and tar greater than 1/8", and stones and wood greater than 1/4".

DENSITY: Woods End measures density on the sample as it is received, at a packing pressure simulating a pile depth of four feet. The result is reported in lbs/cu.ft, and lbs/cu.yd. The fresh density of compost gives a good indication of *porosity*, which determines the rate that air and oxygen can move through a pile, either by natural or mechanical ventilation or by diffusion. Active compost should have a porosity—*i.e.* percent air volume— of 40-60% to ensure adequate oxygenation, also depending on pile size, oxygen demand rate, and means of ventilation. Porosity of most compost can be estimated from the reported density according to the following table:

Density lbs/cu.yd.	400	750	1100	1450	1800
Porosity, % Air Volume	80	60	40	20	0

RESPIRATION RATE: (Carbon-Dioxide Evolution): This test contributes to understanding stability and maturity from a microbiological basis. Woods End reports decomposition in two ways. The carbon evolved *in relation to total carbon* indicates freshness or stability of organic matter (see table below). The total quantity of carbon evolution *in relation to wet weight* indicates the potential for self-heating and weight/volume reduction. Both results must be taken into account in order to properly understand compost condition and behavior. The actual procedure is based on capturing carbon-dioxide in lab incubation (after a 24-hr equilibration period) at 34°C. Samples that are received dry are re-moistened to the ideal range before the test is performed.

	STABILITY OF ORGANIC MATTER				
Relative Stability	**High**	**Med - High**	**Medium**	**Med - Low**	**V - Low**
C-loss,% of Total C	< 0.2	0.2 — 0.8	0.8 — 1.5	1.5 — 2.5	> 2.5
mg CO_2-C / g VS	< 1.0	1 -- 4	4 -- 8	8 -- 13	> 13
Self-Heating Potential	V-Low	Low	Medium	High	V-High

Interpretation of stability is based on Woods End's own extensive research. Interpretation of self-heating is based on correlation trials between compost and its actual heating, seen in the following table and figure. Stability results from advanced humification acting to reduce the rate of decomposition. Self-heating is dependent on rate of decomposition in relation to the total quantity or mass. If the content of organic matter is high enough, (or if the pile is too large), even a low relative rate can still translate into some heating and oxygen deprivation.

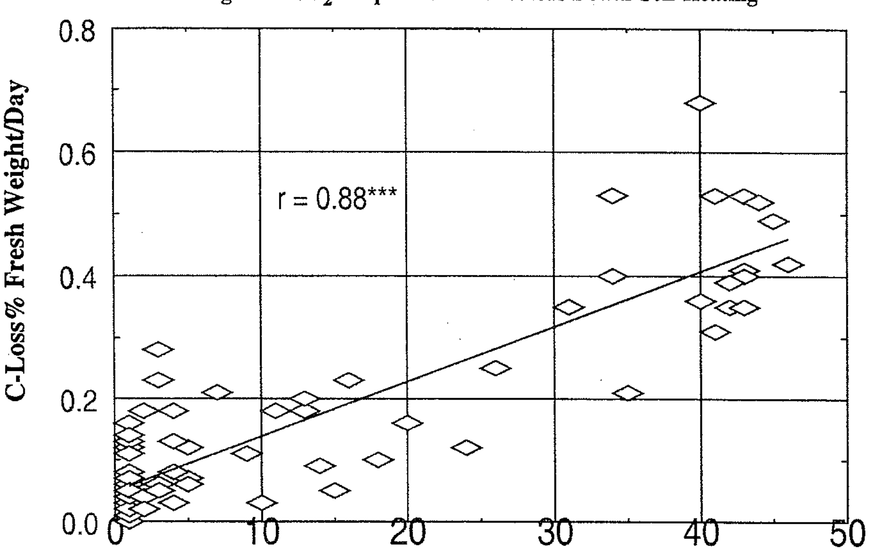
DEWAR SELF-HEATING TEST: The self-heating test is based on a European method for determining "compost ripeness". The test utilizes a special 1-liter Dewar vessel filled with a compost moistened to ideal moisture for the test. The Dewar test is currently listed as a stability/maturity procedure in several states.

The Dewar method gives important information that differs from other stability tests, because it allows for positive feedback during the test. In other words, compost may generate enough respiration to heat up, but when it heats the respiration increases as a function of temperature. With the Dewar test, the highest temperature achieved within a 3-7 days period is recorded and used to rate the stability based on a scoring chart. The Dewar test is, however, not as sensitive to immaturity as is a respiration or Solvita test.

MAX TEMP RISE over ambient	CLASS OF STABILITY	DESCRIPTION OF STABILITY	SELF-HEATING POTENTIAL	TYPE
0 – 10°C	V	Mature to very mature compost	V-Low	Finished
10 – 20°	IV	Maturing, curing compost	M-Low	Compost
20 – 30°	III	Moderately active	Medium	Active
30 – 40°	II	Immature, very active compost	M-High	Compost
40 – 50°	I	Fresh, raw compost	High	Raw Feedstock

The relation of the respiration rate to self heating in a Dewar is confirmed in the following figure:

Figure 1. CO_2-Respiration Rate versus Dewar Self-Heating



In the graph on the left, laboratory respiration rate as CO_2 evolution is shown in comparison to the recorded maximum heating in a Dewar flask, indicating good agreement between the different measures.

Decomposition rate is also used to estimate the release of Nitrogen after soil-application. If the C:N ratio is < 20, the relative respiration rate may be closely correlated to the quantity of nitrogen which is likely to be made available to crop growth during the current growing season. Ranges observed are between 5 and 40% N-release over the entire stability scale.

HEAVY METALS: Heavy metals are regulated in certain types of waste, including bio-solids or composts derived from operations that exceed certain minimum annual tonnage limits (consult your state rules). To evaluate the significance of the levels of metals in any material, it is important to understand both the concentration in the sample *and* the loading rate to soil. In other western countries, the final soil concentration is also regulated.

The federal EPA503 rule establishes acceptable levels and loading rates for sludge (biosolids) compost where more stringent state rules do not already apply. The following table gives the guidelines. For all other composts (and raw wastes), the EPA 503 levels are often used by individual states. European countries have metal limits for horticultural use which are considerably stricter than EPA biosolids rules and are generally used by all composters and universally applied by organic growers. These levels are also shown in the following table. Certification under Woods End's QSAP program also requires achieving European metal limits in contrast to the EPA limits.

HEAVY METALS: Allowed Concentrations in Biosolids and Composts.

ELEMENT	SYM-BOL	EPA Sludge Rule Max. Allowed Conc. of Pollutant mg/kg (pre-1993) — 503		EPA Max Annual Loading Rate, kg/ha — lb/a		Woods End QSAP and European Maximum Limits, ppm
Arsenic	As	10	41	2.0	1.8	n/a — n/a
Cadmium	Cd	10	39	1.9	1.7	2.0
Chromium	Cr	1000	1200	150	134	100
Copper	Cu	1000	1500	75	67	100
Lead	Pb	700	300	15	13	150
Mercury	Hg	10	17	0.85	0.76	0.5
Nickel	Ni	200	420	21	19	50
Zinc	Zn	2000	2800	140	125	400
Boron	B	300*	300*	6	4*	300
Molybdenum	Mo	-	18	0.90	0.80	10
Selenium	Se	36	36	5.0	4.5	25

VOLATILE ORGANIC ACIDS (VOA): The presence of volatile organic acids such as acetic, butyric, propionic and lactic is an indicator of partial anaerobic fermentation and instability in so far as composting is concerned. Woods End has adapted the test to interpretation of composting efficiency and potential phytotoxicity. A compost may be immature and not contain appreciable VOA, yet it is unusual that a mature compost should have appreciable VOA. VOAs are moderately odorous and are responsible for a considerable amount of nuisance complaints at composting operations. In addition, VOAs are largely responsible for phytotoxicity (plant-seedling toxicity). For compost quality interpretation, the following levels are suggested by Woods End:

VOA Rating	V-Low	Med-Low	Medium	High	V-High
VOA, ppm (dry)	< 200	200-1,000	1,000-4,000	4,000-10,000	>10,000

PHYTOTOXICITY and Seedling Growth Response: Phytotoxicity or poor plant response can result from several factors including high amounts of heavy metals, oxygen demand, salts, ammonia, and volatile organic acids. With compost materials it is generally the latter three which trigger a toxicity to plants. The importance of the phytotoxicity tests using actual plants as opposed to mere interpretation of analytical data is that the plant tests do not always necessarily correlate with quantitative lab tests which may not clearly indicate a potential for phytotoxicity. Furthermore, the application of composts to soils and for potting-mix formulation requires verified absence of toxicity factors. Woods End has standardized a phytotoxicity procedure using cress and wheat seedlings in a blended peat based mix. Germination rate and seedling weight are reported as a percent of the control (Pro-Mix BX) and are judged as follows:

Germination, % of Pro-Mix Control	Phytotoxicity Classification	Plant Weight, % of Pro-Mix Control	Phytotoxicity Classification
> 85	V — Non-Toxic	> 90	V — Excellent
70 – 85	IV — Moderately Toxic	80 – 90	IV — Good
50 – 70	III — Toxic	65 – 80	III — Fair
30 – 50	II — Very Toxic	40 – 65	II — Poor
< 30	I — Extremely Toxic	< 40	I — Extremely Poor

SOLVITA® MATURITY TEST: The Solvita test measures respiration and ammonia evolution in a specified volume of compost and gives a semi-quantitative color response accurate over a very wide range of CO_2 and NH_3 levels. The test may be used both in the lab and on-site as a field procedure to enable producers and users to make on-the-spot stability determinations. The Solvita test is currently accepted as an official respiration test in 9 states and also in Denmark, Sweden and Norway, where Solvita values of >6 are generally regarded as acceptable for finished compost. The Solvita Maturity Index is derived from both the CO_2 rate and the volatile ammonia result (see tables provided with the Solvita test).

PATHOGENIC ORGANISMS: The content of potential human pathogens depends on the treatment and age of any biosolids or organic waste material. EPA regulates content of potential pathogens in biosolids (sludge). In some cases, the same regulations are applied by states to determine safety of food waste or other composts. Woods End can provide details of the regulations for each state. The pathogen tests required under EPA-503 rule include *Salmonella*, fecal *Coliform* and in certain cases *Helminth Ova* and *Enteric viruses*. The EPA 503 specified procedure is started on samples received within 24 hrs of sampling. Results are reported per unit gram or 4g of sample, on a dry basis, as most-probable-number (MPN), colony-forming-units (cfu/g) test or plaque-forming-units. Materials containing more than 1000/g fecal coliform or 3 units/4g *Salmonella* are not acceptable as type A materials.

QUALITY SEAL OF APPROVAL- Compost classification is performed by Woods End as part of the Quality Seal (QSAP) program offered. There are 6 types of compost which recognized and approved as distinct groups. For each group, specific minimum test traits must be achieved. Please request separate information for this.

Recognized "TYPE"	DESCRIPTION OF THE DEFINING TEST PROPERTIES	USES ALLOWED UNDER QSAP
Seed Starter	Fine texture, high air volume and water-holding capacity, mature organic matter, low salinity, low NH_4, high available-N, moderate nutrient release potential	General plant substrate for starting seedlings in shallow containers for general gardening and later transplanting.
Container Mix	High air volume and water holding capacity, mature organic matter, low salinity, low NH_4, moderate to coarse texture, moderate nutrient release potential	Medium to large containers for growing out, nursery stock, house plants, and flowers.
Garden Compost	Med-high organic matter, moderate to high available nutrients and nutrient release potential, mature organic matter, M to MH salinity; low C:N ratio, low NH_4:NO_3 ratio	All-purpose garden usage and in greenhouses, incorporation in soil or container media at medium to medium high rates appropriate to soluble nutrient levels.
Topsoil Blend	Simulates rich native topsoil, moderate to high (for soil) organic matter, low C:N ratio, low salinity, stable, low NH_4:NO_3 ratio	Topsoil replacement, direct seeding, lawn-care, soil repair and garden raised beds.
Mulch	High organic matter, moderate to high C:N ratio, low to very low salinity and soluble nutrients, low NH_4:NO_3 ratio	A course blend for surface application only, under shrubs and for general non-growth purposes; and surface organic matter improvement
Natural Fertilizer	Dry-stable, spreadable, low dust, passes pathogen tests, high available nutrients, and rapid nutrient release potential	A high nutrient product best suited to be used sparingly to add nutrients to soil.

COMPOST ANALYTICAL PROCEDURES REFERENCE

Physical Parameters	Units	METHODS REF
Density	lbs/yd^3 g/cc	ASA 41¶
Water Holding Capacity (WHC)	% as is	TMECC Ø
Total Solids (alt. Moisture Content)	TS%	EPA 160.3 †
Dewar Self-Heating	Temp. max °C	IEPA-94°, BGK
Chemical Parameters		
pH	- logH$^-$	EPA 150.1
Volatile Organic Acids (VOA)	ppm dm	SM 5560C
Cation Exchange Capacity (CEC)	cmol / kg	ASA 41-2.2
Conductivity (Salinity)	mmhos/cm - dS/m	EPA 120.1
Volatile Solids (VS)	VS% dm	EPA 160.4
Organic Matter (OM)	VS-TKN%	modified EPA 160.4
Total Kjeldahl Nitrogen (TKN)	TKN% dm	EPA 351.3
Ammonium Nitrogen (NH_3 + NH_4)	NH_4-N ppm	SM 4500-NH3G
Nitrate and Nitrite Nitrogen	NO_3-N, NO_2-N ppm	SM 4110 B‡
Minerals and Metals: P K Ca Na Mg Cl Fe Mn Cu Zn Cr Pb Cd Ni Al B Hg Mo	mg /kg	EPA Methods 202.1 — 265.3
Biological Microbiological Parameters		
Respiration Rate (CO_2-Evolution)	CO_2-C / g VS / day	ASA 41-2.2, TMECC Ø
Nitrogen-Mineralization	ppm NO_3/ 11 weeks	
Salmonella (EPA 503)	MPN/4g TS	SM 9260 D
Fecal Coliform (EPA 503)	cfu / g TS	SM 9222 D
Helminth Ova	ova / g TS	EPA 600/1-87-014
Enteric Virus	pfu / g TS	ASTM D4994-89
Cress Test, Phytotoxicity	% germination % growth	WPCF* TMECC Method
Solvita Test CO_2-respiration and NH_3-volatilization	0 - 8 CO_2 1 - 5 NH_3	TMECC Method; Approved in; CA, CT, TX, FL, IL, ME, MN, NJ. NM OH, WA **

Notes:

¶ Methods of Soil Analysis, American Society of Agronomy, Soil Sci. Soc., Madison WI

Ø TMECC - Test Methods for Examination of Compost. DRAFT (2000) A Compost Council recommended procedures manual. U.S. Compost Council (manuscript only)

† EPA-600 Methods for Chemical Analysis of Water and Wastes. US EPA (RCRA) (and/or) SW-846 Test Methods for Evaluating Solid Waste USEPA 1987 (NPDES)

BGK - Bundesgutegemeinschaft Kompost (Germany Compost Association) Test Manual 1998

° IEPA– Illinois EPA Regulatory Methods 1994

‡ SM = Standard Methods for the Examination of Water & Wastewater, 20th ED. WEF

* Research Journal, WPCF Vol 62:7:853–859

** Required by: WA-DOT, CalTrans, TX-DOT, NM-BM, CT-DOT, Mass-DOT. Approved for substitute to lab respiration/stability testing in all other states listed

ASTM- American Society of Testing Methods, Philadephia

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