INTERPRETING WASTE & COMPOST TESTS

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prepared by Woods End Research Laboratory

SOLIDS / MOISTURE / Water CAPACITY: There is no absolute moisture level which is correct or ideal for manure, composts or waste products. Ideal moisture depends on handling technlogy and processing goals. Biologically, optimal moisture depends on a sample's water holding capacity (WHC). The Woods End report gives WHC% on a dry and as is basis estimated from the content of organic vs non-organic solids. Optimal biological activity for composting occurs at up to 80-85% 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. A low organic matter material (e.g. 30% OM), is adequately wet at only 30 to 40% moisture. A high organic sample, typical of a fresh compost mix, will require from as much as 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. In reading the repot make sure the two sets of numbers of compared.

pH and **Carbonates**: The pH of any material must be interpreted in view of the origin and the intended use and the type of extraction used in preparing the sample. Lime- treated wastes may have moderately high pH (up to 9.0), and waste treated with ash or hydrated lime may have a very high pH (up to 11.0). In conjunction with elevated pH, free lime (carbonates) may be present and are reported on a scale of low, med and high (1-2-3). 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 8.4, where it becomes potentially harmful to plants, and is associated with odor and ammonia loss. Soils and growing medis typiclly use saturated paste methods to estimate pH although it is becoming common to see pH values in 1:5 extracts.

ORGANIC MATTER: Organic matter represents combustible content or "volatile solids" (VS) and is typically reported in terms of total weight loss on ignition as VS or OM. Organic matter may also be surmised from a total-carbon analysis where it is reported as TOC. Conversely, carbon may be surmised from OM and Woods End finds in composts it comprises typically 54% of VS. As with moisture, there is no absolute level of carbon or 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 during processing. The OM test forms the basis for determining the sample C:N ratio (see later).

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 mature compost it is expected to find appreciable amounts of nitrate (NO_3). 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. Woods End reports the percent of total nitrogen which is found to be immediately soluble, useful where fertilization is concerned. Also reported is the amount of ammonium-nitrogen which is volatile as ammonia vapor (NH_3) based on the pH, and subject to immediate loss. Volatile NH_3 values exceeding 15% of total-N are unusually high. If a sample possesses a medium to low pH (<7.5) ammonia losses are negligible. 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 a respiration test). Thus, immature compost with a CN < 25 will release more nitroigen than a mature compost of similar CN. Our research indicates that nitrogen release from manures applied to soil may vary from 20% up to 75% and for composts from 5 to 35%, 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.In some regions, a product is not considered to be a compost unless the C:N is less than 25:1.

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. Extracts made by 1:5 method can not be readily interpreted. 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.

Evaluation of SALINTY 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 (OVERS) CONTENT: Oversize matter that does not pass a 1/4" standard sieve is excluded from all analyses (except fresh density --- see below) and shown in the report as *inert oversized matter*. This category includes man-mades such as metals, plastic, glass, stones and wood fragments. The percentage of 1/4" overs is useful in reporting particle size and is the first step in some standards where overs are required in a certaain amount.

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: This test is based on a 2-decade old European method for determining “compost ripeness” by measuring reheating in a special 1-liter “Dewar” Flask. The test has undergone evolution and is currently recognized in a few states, and widely used within Europe. The method provides valuable information that differs from other stability tests, for it allows positive feedback from self-heating to act on the test result- in other words, compost generates respiration to heat, and theheat cause respiration ti increase until a plateau is attained potentially even in a thermophilic range. This plateau or highest temperature is normally achieved in a 3-7 day period and therefore the test is very time-consuming. The accuracy of the test is dependent on maintaining constant ambient surroundings and by holding the sample to 50% of WHC instead of the customary 70-85% used in respiration tests. Two schemes for interpetation are recognized, as below indicated, on the left for the traditional European approach, and on the right, as recommedned by modern microbiological interpretation of compost heating.

Max Temp (TMax ^{o}C) in Flask*	**Original CLASS OF STABILITY**	**DESCRIPTION OF STABILITY (based on EU std)**	**Max Temp (TMax ^{o}C) in Flask*[a]**	**Class**	**Recommended Interpretation**
< 30 ^{o} C	V	Finished	0 – 25^{o}	A	mature, stable
30.1 - 40^{o} C	IV	Curing compost			
40.1 - 50^{o} C	III	Moderately active	25.1 – 45^{o}	B	Mesophilic, active
50.1 - 60^{o} C	II	Very active, immature			Thermophilic, v.
> 60^{o} C	I	Fresh, raw waste	> 45.1 ^{o}	C	active

a. Max temp assuming ambient is 20^{o} C. Test invalid if ambient > 25^{o}

HEAVY METALS: Heavy metals are regulated at both state and federal leveld in certain types of organic waste including sludges or some composts or any organic waste exceeding minimum annual tonnage limits (consult your state rules). It is important to understand the Pollutant Concentration (PC) in the sample (under which cumulative loading rates do not have to be monitored), the *Maximum Allowable* concentration *and* the cumulative pollutant loading rate (CPLR) which must be monitored for materials exeeding PC to soil. In other western countries, the final soil concentration is also regulated. The federal EPA503 rule limits are often used by individual states for other than only biosolids and generally the PC is used as an upper limit. Europe has metal limits which are stricter and are more realistic for consumer type compost products where heavy usage is anticipated. These levels are also shown in the following tables.

HEAVY METALS: Allowed Concentrations in Biosolids and Generally in Composts.

ELEMENT	**SYM-BOL**	**EPA Max. (PC) mg/kg**	**EU-Standard Max Conc mg/kg**
Arsenic	As	41	n/a
Cadmium	Cd	39	2.0
Chromium	Cr	1,200	100
Copper	Cu	1,500	100
Lead	Pb	300	150
Mercury	Hg	17	0.5
Nickel	Ni	420	50
Zinc	Zn	2,800	400
Boron	B	na	300*
Molybdenum	Mo	na	10
Selenium	Se	36	25

VOLATILE ORGANIC ACIDS (VOA): The presence of organic acid also called volatile fatty acid or extractable acid such as acetic, butyric, propionic, lactic, valeric 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 , potential phytotoxicity and viability for methane biogas production. 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 (Fafard #2) and are judged as follows:

Germination,% of Pro-Mix Control	Phytotoxicity Classification	Plant Weight, % of Pro-Mix Control	Phytotoxicity Classification
> 90	IV — Non-Inhibitory	> 95	V — Excellent
75 – 90	III — Moderately Inhib.	80 – 95	IV — V. Good
50 – 75	II — Very Inhibitory	70 – 80	III — Fair
< 50	I —Extremely Inhib.	40 – 70	II — Poor
		< 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).

SOLVITA MATURITY INDEX	APPROXIMATE STAGE OF THE COMPOSTING PROCESS	MAJOR CLASS
8	Highly matured, well aged compost, for all uses	"FINISHED" COMPOST
7	Well matured compost, cured, ready for most uses	
6	Compost finishing curing; erady for some uses	Post Active
5	Curing can be started; limited uses	Limit - Very Active
4	Compost in moderately active stage	Highly Active
3	Very active compost; not read for most uses	
2	Very active, fresh compost	odorous - "RAW" COMPOST
1	Fresh, raw compost; extremely unstable	

PATHOGENIC ORGANISMS/ Indicator Microbes: 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 (or)* 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 total solids, as most-probable-number (MPN) or plaque-forming-units. Materials containing more than 1000/g fecal coliform or 3 units/4g *Salmonella* are not acceptable as type A EPA materials.

Compost and organic amendment hygiene is of great significance for end-use food production (and consumer handling). Woods End's view is that it is unacceptable to have detectable *E. coli* or *Salmonella*, or fecakl coliform greater than 1,000 MPN/g. The USDA has extablished cleanliness standards for compost teas, which are also examined by Woods End. The limits are < 135 cfu/ 100 ml *E. coli*. *Any* compost containing appreciable *E. coli* (>100 MPN) should be examined for *E. coli 0157:H7* which should be non-detectable at < 0.02 cfu / g (< 1 /50g).

Hygiene Microorganism	SIGNIFICANCE OF THE ORGANISM	Testing typically required for	Relevant - Agencies Countried
fecal coliform	most common indicator organism for presence of fecal matter from warm blooded mammals and birds	sludge; compost	EPA: USA; WHO
Salmonella	pathogenic organism shared by domestic livestock and humans	food; sludge; compost	FAO; EPA; EU; OMRI
E. coli	A fecal coliform; common indicator of warm-blooded fecal matter; includes many pathogenic forms	food; sludge; compost	FAO; EPA; EU; OMRI
E. coli 0157:H7	highly pathogenic strain of *E. coli* infectious at very low doses	food	
fecal streptococcus* & *Enterococcus	very strong fecal indicators; more resilient than fecal coliforms in environment	water; sludge; compost	EPA; EU
C. perfringens	Pathogenic spore-forming obligate anaerobe of fecal origin	water testing; irrigation water	
Listeria spp	Widespread in environment surviving cool temperatures; some strains highly pathogenic; associated with food poisoning, miscariages and meningitis	cooked food; milk	

MATRIX Classification- Compost classification is performed by means of a statistical multi-array using actual analytical test results. The array scores the goodness of fit or "match" within a best use category. There are 6 types of use recognized. The minimum level score to meet any category is 75%. Mulitple category listings are possible. Scores <75% are registered as Quality Control composts. Please request separate information for this.

COMPOST ANALYTICAL PROCEDURES REFERENCE

Physical Parameters	Units	METHODS REF
Density	lbs/yd^3 g/cc	TMECC 03.03, ASA-41¶
Water Holding Capacity (WHC)	g 100g as is	WERL
Total Solids (alt. Moisture Content)	g 100g TS	TMECC 03.09
Dewar Self-Heating	Tmax in °C	TMECC 05.08D; BGK
Man-Made Inerts, Plastic, Glass, metal	g 100g TS	*modified* TMECC 03.06- 03.08
Chemical Parameters		
pH, saturated paste	- log H^-	EPA 150.1; TMECC
Volatile Organic Acids (VOA, VFA)	mg kg TS	SM 5560C / HPLC-UV
Cation Exchange Capacity (CEC)	cmol / kg	ASA 41-2.2
Conductivity (EC), saturated paste/slurry	dS m	TMECC 04.15
Volatile Solids (VS) (Loss on Ignition)	VS dm	*modified* TMECC 03.02
Organic Matter (OM)	VS-TKN%	LOI @ 550C - Total-N
Total Kjeldahl Nitrogen (TKN)	TKN% dm	TMECC; MAP
Ammonium Nitrogen (NH_3 + NH_4)	NH_4-N ppm	SM4500-NH3G
Nitrate and Nitrite Nitrogen	NO_3-N, NO_2-N ppm	MAP; HPLC UV
P K Ca Na Mg Cl Fe Mn Cu Zn Cr Pb Cd Ni Al As B Hg Mo Se	mg kg TS mg kg TS	MAP TMECC 04.06
Biological Microbiological Parameters		
Respiration Rate (CO_2-Evolution) DRI-ASTM (Oxygen Consumption) Oxitop	CO_2-Cmg g TS day mg O_2 g VS hr mg O_2 g VS 3d	TMECC 5.08AØ ASTM-5975-96 CEN Draft
Solvita Test for CO_2-respiration and NH_3-volatilization**	0 - 8 CO_2 1 - 5 NH_3	TMECC 5.08E;Approved in CA, CT, TX, FL, IL, ME, MN, NJ. NM OH, WA
Salmonella (EPA 503) *Salmonella* (presence/absence) *Fecal Coliform* (EPA 503) *E. coli* *E. coli 0157:H7* *Fecal Streptococcus* *Clostridium perfringens* *Listeria* spp.	MPN 4g TS PA cfu g TS MPN g TS MPN g TS MPN g TS cfu g TS MPN g TS	EPA #1682 TMECC 7.02A EPA #1680 EPA 1680 + SM9221F *modified* FDA BAM SM9230B *modified* FDA BAM *modified* FDA BAM
Cress Test, Phytotoxicity	% of Fafard Control	modified ACSD and BGK
Disease Suppression	% inhibition	modfied after Hoitink, Krause et al.
Lemma sp. (Duckweed) Toxicity Test	% inhibition	modified after SM 8211-A.
Viable Weed Seeds	>0.8 / liter	TMECC 05.09-B
Herbicide BioAssay	0 -5 severity scale	Bull. Env. Contam. Tox

ASTM- American Society of Testing Methods, Philadephia
MAP- Manure Methods of Analysis. Univ of Wisconsin A3769 (2003)
¶ Methods of Soil Analysis, American Society of Agronomy, Soil Sci. Soc., Madison WI
Ø TMECC - Test Methods for Examination of Compost. (2000) U.S. Compost Council & USDA (CD-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 Methods Manual 1998
ACSD - Association of Swiss Composters, Methods Manual (2003)
‡ SM = Standard Methods for the Examination of Water & Wastewater, 20th ED. Water Env Federation
** Required by: WA-DOT, CalTrans, TX-DOT, NM-BM, CT-DOT, Mass-DOT.