COMPOST QUALITY STANDARDS & GUIDELINES

Final Report

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COMPOST STANDARDS & GUIDELINES

Report to NYSAR[3]

by

Woods End Research Laboratory, Inc.

"Markets for organic matter will not mature until farmers can be confident about the product they are buying."
Gary Gardner,
World Watch Institute, 1998

SUMMARY:

The concept of establishing standards specific to compost and the promotion of quality criteria in order to bolster the compost industry and to aid growth of new markets has been slowly emerging over nearly two decades through-out the western world. Recently, several European countries have adopted specific standards.and many other countries are in the process of doing so. In the United States, efforts have been very scattered. The only existing quality guidelines specific to compost are presently promulgated by such specific agencies as state DOT's, which have an interest in large-scale compost usage. This report examines the history of compost appreciation, and particularly looks at the emerging awareness of the need to distinguish composts from other re-cycled wastes and common fertilizers. Without such distinguishing features, compost sales may lag. This report also examines potential conflicts in setting new standards. ❑

STRUCTURE AND INDEX OF THIS DOCUMENT

About the Title Picture...

In some countries, composters seek to achieve certain quality standards and in return receive quality labels. The certification and approval process defines and promotes compost products as distinct from other soil amendments and fertilizers. Pictured are Seals from Italy, Austria, Germany, Holland, Belgium and the EEC.

STATUS OF NATIONAL COMPOST STANDARDS

There is no simple way to give a summary concerning compost quality standards as they exist in the world, and how they arose. This document presents a variety of established and published standards. This study is based on gleaning conference proceedings, government reports, and private association guidelines. The period of time covered in this review is roughly the last 10 years.

Many countries are now beginning to routinely publish compost guidelines with implied standards. Portions of these guidelines are required by certain laws; others are obscure. This makes it hard to distinguish legal as in the case of legislative from voluntary systems of standards. The purpose of this report is, however, not to determine standards purely on a statutory basis, but to present an overview of such standards. From this, we may hope to gain a better understanding of what common factors exist from which successful standards - whether mandatory or not - could be developed in America.

A quick comparison of compost standards of various countries shows Europe to be fairly well-developed, while the rest of the world, including the United States, lags significantly behind. Some of the causes of this difference are examined. One probable reason for the discrepancy seems to be political in nature. Also evident are differing scientific opinions regarding how tests on compost should be conducted, or what constitutes “critical levels” in regards to environmental cleanliness of compost.

At a recent international trade meeting in Oxford England a Swiss speaker from a federally funded research institute remarked that if compost was a world commodity, there is evidence that it would precipitate trade wars. He was referring to the sharp demarcations in how the product is "defined", it at all. The following table (Table 1) gives an overview of the existence of such definitions and standards in various countries, as given in the recent Vienna Conference "Steps Towards a European Compost Directive" (O-Com,1999)

Table 1: Status of National Compost Guidelines (O-Com, 1999)

Austria	Fully established quality assurance system
Australia	Comprehensive quality criteria and analyzing methods.
Belgium	Established quality assurance system in Flanders. Brussels and other regions may follow Flanders example.
Canada	Developed standards; discussion re province specifics; trade-association quality assurance system
Denmark	Recently implemented quality assurance system with standardized product definition, analysis methods
France	Limited quality criteria, research program underway for quality management
Greece	Basic Solids Waste rules; no official compost std.
Germany	Fully establish quality assurance system; Private Association maintains standards
Hungary	New Compost Quality Association
Italy	New decree in place for waste source separation; Private compost association formed to evaluate standards
Japan	New waste decree for waste separation; 2001-Standards not developed
Luxemburg	Some compost plants follow German quality assurance system
Netherlands	Fully established quality assurance and certificate system
Norway	Compost quality studies underway; criteria proposed for 3 quality classes
Spain	Compost guidelines established and proposal for quality certification system in the Catalonia region
Sweden	Recently implemented standards and compost declaration system
Switzerland	Established minimum quality standards
United Kingdom	Proposed quality standards by private composting association
USA	Compost regulated under biosolids or fertilizer rule; DOT use-standards in 13 states; Private association

Standards and guidelines are promulgated by a variety of agencies. Indeed, difficulty exists in assessing compost standards owing to the great range of sponsors, both private and public, that are evident. The following table gives regulations and labels that are presently available (Table 2).

Table 2: Status of Compost Quality Seals by Country (Modified, after Centemero, 1999)

Country	Regulation or Guiding Rule	QUALITY SEAL
Austria	ÖNORM S2220 1993 three classes of compost - I, II, III	
Australia	Bureau of Standards	none
Belgium	Agricultural Agency two classes	
Canada	Sludge Rule; Private Association (CCA)	/
Denmark	Danish EPA 1/06/2000	/
France	Fertilizer Law	/
Germany	Federal BioWaste Decree (BioAbfallV) 1998 Federal Sludge Decree (KlarschlammV)1993; Private compost association (RAL)	
Hungary	Private Association : 1999	/
Italy	Fertilizer Law (3/98); Private compost association	
Luxemburg	Draft Federal, taken from German RAL	
Netherlands	Waste Law, two classes: Clean Compost; Very Clean Compost	
Norway	EPA	/
Spain	Bureau of Waste/Environment	/
Sweden	Swedish EPA	/
Switzerland	Federal Standards “Minimum Quality”	/
United Kingdom	sludge law; private Compost Association	/
USA	Biosolids Rule governs all waste State Agencies with limited standards; 1 private label, no national seal	

WHAT'S TO DECLARE IN COMPOST?

Inorganic chemical fertilizers that carry a label by law must declare their N-P-K (nitrogen - phosphorus - potassium) content according to rules established more than half a century ago. However, compost, a product that contains nutrients and organic matter, is not subject to any systematic rules for reporting its content, its qualities or potential risks. There are no labelling rules, and no published guidelines to establish such rules, unless and only if such compost purports to be fertilizer.

The idea that compost is significantly different from inorganic fertilizers is not new; however, until recently the unique properties of compost were overlooked and instead compost has been generally classified as a nutrient-poor "soil amendment". There have been recent changes, for example, within the last 10 years, the American Association of Plant Food Controllers (AAPFCO) altered its official definition of compost with improved terminology.

The special recognition of compost as a potential fertilizer material predates the Wars, and was clearly defined as early as 1932 in the USDA publication “Conservation of Fertilizer Materials from Minor Sources” (Misc Pub 136). In the 1938 Yearbook of Agriculture “Soils and Men” the USDA stated "..there are many materials capable of being composted which possess fertilizer value". This government publication clearly enunciated the view that

> "Instead of burning or discarding these materials, it is advisable to make a compost pile". (USDA, 1938).

After WWII, with the advent of cheap fertilizers, composting as a potential agricultural practice fell into disuse or neglect. With the rise of the organic farming movement, however- which also predates the Wars but only flourished after WWII- composting became associated with "back to the land movement". As recently as 1980, AAPFCO appeared to pan “organic” in its definition in the Farm Chemicals Handbook (FCH, 1980). But the startling publication in 1975 by Washington University's Center for the Biology of Natural Systems (CBNS, 1975), showing favorable comparisons of farms that used only manures and composts as compared to standard chemical practice, began a turning of events that refocused the awareness of the value of soil organic matter and composts. This culminated in an official USDA study "Report and Recommendations on Organic Farming" under Bob Bergland, Secretary of Agriculture (1980) in which perhaps for the first time since 1938 the properties of organic matter and compost were officially lauded. This study reiterated a long known definition of compost:

> "An ancient practice whereby farmers convert organic waste into useful organic soil amendments that provide nutrients to crops and enhance the tilth, fertility, and productivity of soils" (USDA, 1980).

Simultaneous to these events, USDA's Beltsville Agricultural Experiment Station published the first official guideline on composting sewage sludge, originating the “Beltsville aerated pile method” and providing guidelines for use of composted sludge in agriculture (USDA, 1980).

Similar events refocusing interest on natural soil amendments and compost were taking place in Europe in the same time period. Official reports from Governments in Germany and Sweden, among others, were published showing dramatic improvements to soil from "low-intensive" fertilizer practices using little more then compost and "farmyard manure" (Dlouhy, 1977, 1981; German Ministry of Agriculture, 1977).

Following this period of reinvestigation, the waste crisis struck in the mid to late 80's, prompting a dramatic shift in awareness of the need for alternative biological processing of so called biodegradable wastes. The potential damage to the environment by unmonitored (unlined) landfills, the indiscriminate dumping of trash- epitomized in the "Garbage Barge" event - and the potential compostability of trash in landfills, the awareness of the waste of the "throwaway culture", all brought new emphasis to bear on the matter of how society handles its organic waste. Indirectly, this brought composting back into play, only this time into a very different arena of industrial and corporate players.

As an example of the new partnerships that formed to promote composting, in 1986 Maine formed the "Mid-Coast Compost Consortium" loosely partnering representatives of the paper, food and fish processing industry with extension, researchers and private consultants. Their objective was to explore and implement large scale composting as a means to reduce the burden of organic waste accumulation, in this case with a focus on fish and wood residues. The state's first official outdoor, large scale windrow compost project was initiated at that time, perhaps the first of its kind in America (MCCC, 1987).

All across the country in the 80's, similar projects got underway, yet the focus was not necessarily on soil organic matter and certainly not on organic farming. The concept "beneficial re-use" began to be used widely; around the same time sludge was re-coined biosolids, and the national Wastewater Federation became the "Water Environment Federation". Not surprisingly, from where we stand now, many look back to the 80's as a time of enthusiasm matched only by confusing and poorly informed efforts. It is a droll reminder of the recent small beginnings of the era that a researcher at a New England Department of Agriculture had to call all around the Northeast to discover if any laboratories could perform "C:N ratio" analysis in order to formulate a compost mixture (*personal communicatio*n, Bill Seekins).

Concepts of compost quality or compost test standardization were essentially unknown worldwide as recently as 1985. Outside of beneficial yields from compost usage or the reports of raising soil organic matter, there is little evidence of the application of a compost quality verification program. Even within organic farming, compost qualities were not examined closely. The pioneering manual about sludge composting published by USDA-Beltsville only briefly mentioned "stabilization" but did not define it, nor did it discuss when compost is finished, or how that would be determined, if at all. Quality emphasis was focused on potential human pathogen content or in other words, the absence of danger (USDA, 1980).

EMERGENCE OF COMPOST QUALITY FOCUS

The intent and need to report qualities of compost scientifically is a natural outcome of growth of the compost industry. It particularly arises in interaction with an increasingly environmentally-aware public, as well as with health regulators and traditional agricultural associations. However, this push for recognition of compost quality has perhaps had as many opponents as contributors, since it exposes issues of allowable risk, government regulation and market limitations. The mandating of standards has come about surprisingly recently, mostly as a result of European events.

One of the earliest serious investigations of compost quality is the anonymous report from the German Waste Association (RAL) which set forth "Quality Criteria and Application Recommendations for Municipal Waste and MSW-Sludge Composts" (LAGA-10, 1984, in German). This study unleashed controversy by questioning the qualities and properties of composts made from "uncontrolled" mixed wastes, in particular shredded MSW and mixtures containing sludge. In this same period, between 1982 to 1990, scientific surveys of heavy metals in household wastes galvanized this direction (Bidlingmeier, 1982, 1987). A decade later, the issue of contaminants in hazardous waste derived fertilizers and metals in fertilizers broke over America (EWG, 1997).

These studies and reports reinforced environmental concerns about the dangers of indiscriminate recycling and poorly defined composting of “decomposable” trash. In this same time period, the concept of source-separated "bio-composting" was established in the Hessen region of Germany by Fricke and co-workers, beginning with the first "bio-bin" separation project around 1982 (Fricke, 1988; Vogtman et al, 1989).

W. Brinton photo (1996)

Fig. 2 - MSW Compost in French Vineyard - Lack of quality control led to a high percentages of physical contamination visible at end-user sites. Compost in photo contained plastic, glass, rubber and leather.

With focus now on home separation for successful regional composting, essentially the same group of workers published a series of reports and studies detailing the positive effects of source separation and examined partitioning of contamination in bio-composts and variations of them. These studies provided dramatic evidence that poor separation and handling standards would most likely result in large and unacceptable increases in concentration of undesirable and hazardous ingredients, including PCB's, PAH's, dioxins and obviously heavy metals as well as glass, plastic and other physical inerts (Vogtman et al., 1989) - see photo- french vineyard compost.

In 1990, Bertram Kehres, now head of the German Compost Quality Association (Bundesgütegemeinschaft Kompost or BGK- referred to in reverse as the "KGB") published his doctoral thesis concerning "Quality of Compost from Differing Source Materials" (Kehres, 1990) which emphasized the possibility of producing low contaminant composts. It should be noted that around the same time another doctoral thesis in Germany by Bernd Jourdan (Univ. Stuttgart) outlined a procedure called the Dewar Self-heating test (Jourdan, 1988), later adopted as an official test in Germany and now a *de facto* standard throughout Europe for determining compost stability (see section on testing, later).

A key element in most of these basic European studies concerning compost contamination — studies which were hardly noticed elsewhere in the world— is that significant data had been collected not only showing sources and extent of compost contamination, but showing that clean composts - low in contamination - were within practical and economic reach.

Furthermore, these same studies document background levels of metals and other contaminants in soils, leading to conservative standards that are realistic and ecologically conserving. There is some new concern about this since European countries are considering lowering the heavy metal limits further, which will be discussed (Bidlingmeier & Barth, 1993).

SOURCE SEPARATION FOR LOW-CONTAMINANT COMPOST

It may be helpful to look at some of the evidence of the difference in contamination resulting from composting non-source separated wastes and so-called "bio-waste" (Bioabfall) which is source-separated, meaning all organic fractions are collected separate to regular household trash. Kraus examined compost from seven regions which were paired into either MSW-based compost or source-separated compost. He found that the bio-waste composts contained on average 1/4 the metals content of MSW composts (see Table 2). Several other workers have published similar data (Wiemer & Kern, 1989).

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Table 3: Heavy Metal Content in MSW vs. Source-Separated Compost in Relation to Standards (Source: Kraus & Grammel., 1992)

Element	Mixed MSW Compost (Avg 4 regions) mg/kg	Bio-Waste Compost (Avg 4 regions) mg/kg	German Standard mg/kg
Pb	420	83	150
Cu	222	41	150
Zn	919	224	500
Cr	107	61	150
Ni	84	26	50
Cd	2.8	0.4	3
Hg	1.9	<0.2	3

The extensive studies by Kraus and Grammel at the University of Tübingen and Poletschny of LUFA, Bonn (Poletschny et al., 1990) concerning the transport and fate of heavy metals, PCBs and dioxins in the waste stream and composts raised concern regarding indiscriminate mixing. This lead to a gradual shutdown of MSW composting plants, starting first in Germany and sweeping Switzerland, Austria and eventually France (Kraus & Grammel, 1992; Weimer & Kem, 1992).

The German Agricultural and Horticultural Association drafted a recommendation for lower metal limits wherever compost is used for intensive vegetable production (see Table 3). The reason stated was that gardeners normally use very heavy rates or do not control application rates at all, and certain vegetables such as lettuce, spinach and celery are known accumulators. For comparison, we show also data for typical soil background metal levels published for European soils.

Table 4: Recommended Metal Limits for Heavy Use Rates of Compost for Vegetables, with Typical Soil Levels

Element	Max. Conc. Recommended for Intensive Compost[a]	Typical Values for SOILS mg/kg[b]
Pb	75	12 - 100
Cu	50	3 - 20
Zn	200	14 - 125
Cr	75	5 - 100
Ni	30	4 - 50
Cd	0.75	0.3 - 0.7
Hg	0.5	0.05 - 0.40

a.German Hort. Assoc; b. source: BodSch(1998)

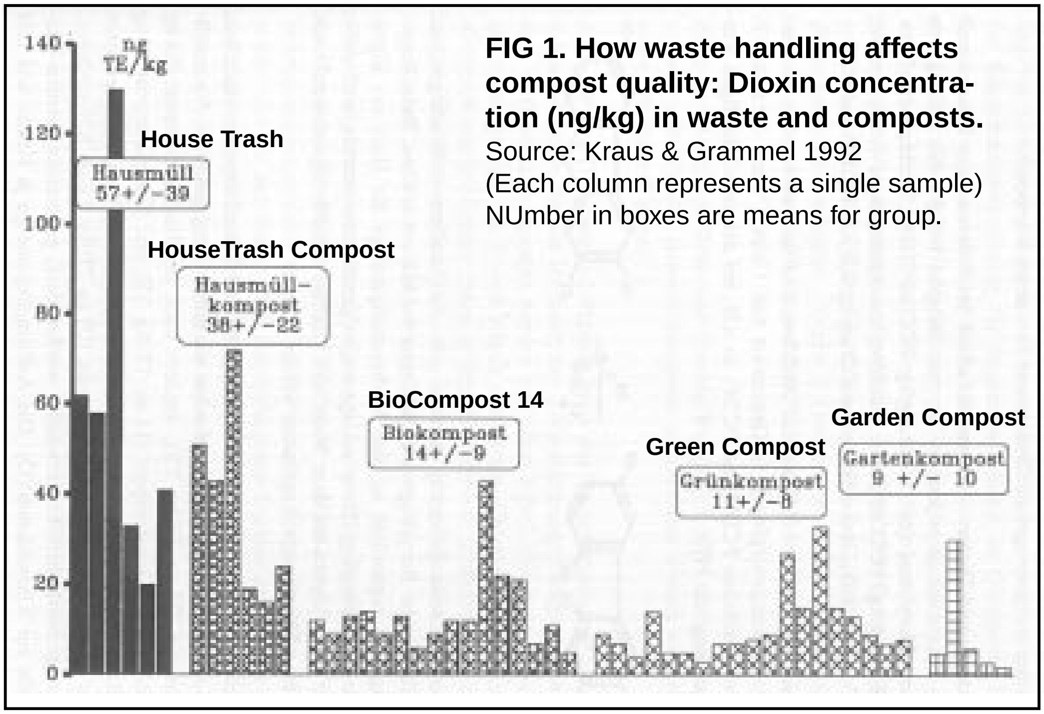

FIG 1. How waste handling affects compost quality: Dioxin concentration (ng/kg) in waste and composts.
Source: Kraus & Grammel 1992
(Each column represents a single sample)
NUmber in boxes are means for group.

In studies on polychlorinated dibenzo-p-dioxins (PCDD) and di-benzofurans (PCDF), Kraus (see Fig. 1) showed an average of total PCDD/F content (TE or toxicity equivalents) of 57 ng/kg in household trash, followed by 38 ng/kg in MSW compost, 14 ng/kg in biocompost followed by 9 ng/kg in garden composts (Kraus & Grammel, 1992). PCBs ranged from 390 ng/g in MSW compost to 104 in biocompost down to 45 ng/g in garden compost. Several other similar studies confirmed that carefully separated wastes or on-farm wastes would result in very low-contaminate levels, so that the basis for the stringent standards eventually adopted was felt to be fully justified.

It was in this time period (1989-93) that EPA's released its proposed rule "Standards for Disposal of Sewage Sludge" (Feb 1989; Final Rule Feb 1993). In this rule the concept of exposure pathways and risk analysis to determine concentration limits for contaminants was developed. The effect was that it relaxed allowable metal loading limits over prior standards, and is presently the most lenient published standard in the world (see loading rates, Table 5).

Table 5: Permissible Heavy Metal Loading, kg/ha/yr - Europe vs. USA[a]

Region	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Europe [b]	0.7	0.15	2.0	12	0.1	3	15	30
U.S.A.[c]	2.0	1.9	150	75	0.85	21	15	140

a.Total allowed ceiling concentrations in soil are approximately 10x for both
b.Based on German Soil Protection Rule, clay soils (BodSch, 1998)
c.For APLR Biosolids- having concentration > EQ but less than Max. Ceiling Conc.

A significant development of the time that influenced thinking about compost quality was the formation in 1990 of the Solid Waste Compost Council in Washington DC. The Council, with principal support provided by Proctor & Gamble, adopted a strategy that followed from EPA's lead but which appeared opposite to the European focus on contaminant-free compost. The Council funded key studies (both in America and Europe) with one objective being to show that inerts and contaminants associated with MSW, especially heavy metals and plastics, could be tolerated in compost without apparent harm to soil and plants.

The result of these efforts in the US and Canada was that enormous discrepancies came into existence in perception of quality and land-application standards that persist to this day. Indeed, international tables on pollution limits from composts frequently show ratios between the highest and lowest allowed concentration by countries; the inclusion of U.S.A. data invariably skews the figures (Swedish Ag University, 1997). As an example, Krogmann and Richards have provided comparisons of American vs. German standards (Krogmann, 1996; Richards, 1992).

A case in point which illustrates the conflict in approach regarding the need for separation and control of contamination is seen in diaper research funded by P&G in Europe beginning around 1991. These projects shifted the emphasis of *total* source-separation in bio-wastes by including disposable diapers in bio-bin waste collection programs. At least three scientific reports on disposable diaper composting were published in Germany and Switzerland (Franke, 1991; Obermeier et al., 1991; Schleiss, 1991). While the findings were mostly inconclusive, they did reveal that zinc-oxide content in diapers from baby creams caused measurable increases by around 60-100 ppm in compost zinc, bringing Zn close to some EU limits (ranging from 300-400 ppm). The studies, which raised hygiene issues, also showed that plastic particles from diapers were impossible to separate from normal compost without double screening. The unexpected reaction to these and other corporate-scientific efforts was the outlawing of diapers in most bio-waste source separation programs.

It can be seen from this limited discussion that both in Europe and sporadically in communities in North America, source separation and composting focused controversy and concern on cleanliness, leading to calls for compost quality standards. Not surprisingly, considering the European studies cited here, in a recent survey of participants of a large international convention on composting that was held recently in Vienna, Austria, a majority of participants thought that MSW composts pose graver risks to the public than do sewage sludges (Amlinger, 1999). This is borne out by very recent European studies that show metal content of sludges to be on average only slightly higher than source separated bio-composts (Hackenberg and Wegener, 1999).

Compost View At The Millennium

There is some evidence that a consensus has emerged among most western countries regarding the need for compost quality characterization methods. Yet, there remain significant disagreements, particularly as to the level of contamination that is accepted for compost, especially within agriculture, and how this is to be monitored and achieved. At the same time, a more biological approach to compost quality has emerged even more recently, with a focus on measuring stability and phytotoxicity.

Differences regarding characterization of compost quality are not only evident between the US and Europe, but also within Europe. For example, in Switzerland the use of opaque biodegradable bags for bio-wastes (i.e. kitchen scraps) is not permissible on account of the belief that citizens will hide inert trash in it (Zürich, 1998). Opposite to this, Germany temporarily banned biodegradable see-through bags in the belief it would encourage the use of plastics in bio-waste programs (BioAbfV, 1998). Many communities in Germany subsequently launched the "waste-sheriff" (Müllsheriff) technology which enables collection trucks to "see through" the walls and bags in biobins by means of low-emission radio-waves and thereby to detect without opening the containers if there is unacceptable contamination.

TECHNICAL COMPOST STANDARDS COMPARED

Compost quality guidelines are relatively new, dating to the mid-1980's. With regard to organic soil amendments, perhaps the only comparable standard similar to what has emerged for compost in some countries is the system of classification of peats (Fuchsman, 1980). Compost has been widely used for decades in organic farming, but issues concerning composition and quality have only recently emerged largely by external pressure (OMRI, 1998).

Comprehensive National Standards

There has been a steady progression of definitions of contaminant limits when considering compost quality. The very first published limits pertained to heavy metals are seen in the late 70's in Europe. In the mid to late 80's contaminants generally entered the discussion, followed by compost maturity and plant-growth properties. These standards and pertinent discussion include:

1 Heavy metal allowable levels

2 Physical composition and inert contamination

3 Pathogenic bacteriology and phytopathogens

4 PTE's (Potentially Toxic Elements)

5 Maturity and plant growth performance

With the inception in1989 of the German Compost Quality Association, and its development of a compost quality seal in 1992, a beginning was made in the direction of common recognition of quality for end-user distribution (Dupre, 1992). In 1989, an evaluation of quality of composts was published for Switzerland, leading to establishing the Kompost Mindestqualität "Compost Minimum Quality" rule (Candinas et al., 1989; 1995; FAC 1995).

Despite these facts, these European standards were not end-user driven. Rather they were dictated by new policies handed down regarding the waste stream, based on scientific studies about sources of contamination. Similar pressures are evident elsewhere and in the United States, where slower progress is evident.

Standards and Seal Programs

Several countries in Europe have some sort of compost grading system, either recommended, required by law, or an Association quality seal program. Germany has had two types of quality seals that can be obtained for composts: the Bundesgütegemeinschaft Quality Seal and the Blue Angel seal (RAL, 1998). Both are authorized under the German Institute for Quality Certification and Declaration (RAL), an agency that has a scope similar to UL in North America. The majority of composters seeking quality certification in Germany choose the RAL-BGK over the Blue Angel Seal: there were more than 200 BGK composters certified under BGK versa 52 under the Blue Angel (Blue Angel statistics, 1998; personal communication, LUFA, 1998). Blue Angel is appears to have abdicated its compost seal to the German BGK program, while the Eco-Label seal is separately administered from Brussels (OJ, 1998).

Figure 1.
SELECTED QUALITY SEALS FOR COMPOST PRODUCTS

The RAL Seal: "Certified Compost"

The Blue Angel Seal "Low Contaminant Compost"

ECO-LABEL

This product qualifies for the EU eco-label, because:

*** it contributes to the reduction of soil and water pollution and minimises waste by promoting its use or re-use.**

A very comprehensive compost declaration system has been devised by the Danish EPA (see later figure). The Australian system, in contrast, is well-designed based on compost end-uses, however, a warning label for composts is required (see Figure 2).

The European ECO-LABEL Seal for Soil Improvers

The European Commission determined in 1992 that a seal of quality could be issued for any qualifying natural soil amendment produced within a member state. This is part of a wider program of issuing eco-labels within specific product groups. In 1998 the Directive was modified and upgraded with specific standards that apply to composts in general, as follows (see Table 5.) The Eco-Label for composts has to date not been widely used (Centermero et al., 1999)

Table 6: Europe Eco-Label Standards Applicable to Composts[a]

Tested Traits	Limits as determined by Test Methods 86/ 278/EEC
Heavy Metals	see table 8
Special Metals	If contains industrial or municipal wastes, then test for: Mo, Se, As, F
Constituents	Organic Matter > 20%; Moisture < 75%; Total-N less than 2% TS
N- P_2O_5 - K_2O application limits	Application rates shall specify not more than: 17g/m2 N - 6g/m2 P_2O_5 - 12g/m2 K_2O
Pathogens	Salmonella non detect in 25g E. coli < 1000 MPN/g
Other:	Contains no offensive odors; No glass, wire or other fragments; No unacceptable weed seeds
Declarations:	Must describe recommended use and application rates; All feedstocks > 10% must be reported; Nutrients, organic matter and metals must be reported; No phytotoxic effects

a.Source: Official Journal of the European Community (OJ, 1998)

COMPOST HEAVY METAL STANDARDS

Of all potential quality standards, heavy metals have been the focus of most attention. Thus it is useful to explore the details of these standards country by country, beginning with an overview of the range of standards that are evident (Table 7). These data of permissible metal ranges reveal significant variation within Europe. However, United States numbers diverge dramatically with regard to allowed Cd, Cr, Cu, Hg and Ni.

Table 7: Heavy metals limit compared: EC states versus U.S.A. - mg/kg

Metal	Symbol	EU- Range	USA biosolids
Cadmium	Cd	0.7 - 10	39
Chromium	Cr	70 - 200	1,200
Copper	Cu	70 - 600	1,500
Mercury	Hg	0.7 - 10	17
Nickel	Ni	20 - 200	420
Lead	Pb	70 - 1,000	300
Zinc	Zn	210 - 4,000	2,800

From this one must consider the metal limits presently used or enforced in various European countries. In some cases, different grades are distinguished as in Austria which has 3 grades and Germany which has two sets of standards.

Table 8: Heavy metals limits (mg/kg) for European countries which do have compost rules

	Countries[a] (for code see key)												
Ele-ment	A	A[b] Class 2[c]	B Agr	B Park	CH	DK	F	D	I	NL	NL	SP	C A,AA
Arsenic	-	-	-	-	-	25	-	-	10	25	15	-	13
Boron	100	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium	4	1	5	5	3	1.2	8	1.5	1.5	2	1	40	3
Chromium	150	70	150	200	150	-	-	100	100	200	70	750	210
Cobalt	-	-	10	20	25	-	-	-	-	-	-	-	34
Copper	400	100	100	500	150	-	-	100	300	300	90	1750	100
Lead	500	150	600	1000	150	120	800	150	140	200	120	1200	150
Mercury	4	1	5	5	3	1.2	8	1.0	1.5	2	0.7	25	0.8
Nickel	100	60	50	100	50	45	200	50	50	50	20	400	62
Selenium	-	-	-	-	-	-	-	-	-	-	-	-	2
Zinc	1000	400	1000	1500	500	-	-	400	500	900	280	4000	500

a.Country Codes: **A** Austria; **B** Belgium; **C** Canada DK Denmark; **F** France; **D** Germany; **I** Italy; **NL** Netherlands; **SP** Spain; **CH** Switzerland
b.Calculated on 30% Organic Matter basis
c.NOTES: Class-2 as Versus Class 1 or Class A vs. AA; Agr -Agricultural use; Park= Horticultural use.

Not all current metal standards are fixed; several countries including Belgium, Italy and the Netherlands have been exploring implementing still lower limits and several may adopt a two class system with the highest class approaching EEC-Organic Rule levels (see Tables 6-10).

Among metal limits some countries expect to lower are: zinc, nickel and mercury, based on current investigations. The metal limits may eventually be so low in some European countries that it may act as an absolute bar on composting for some types wastes (Bidlingmeier & Barth, 1993). Application of biowaste and other composts is controlled by existing soil metal levels. In Germany, according to the new Waste Decree (BioAbfV,1998), compost application to land may require special permits based on soil metals for each soil type, as shown in the following table (Table 9):

Table 9: Absolute soil metal concentrations, based on soil type, over which application of composts is restricted or forbidden, mg/kg [a]

Country	Soil Type	Cd	Pb	Cr	Cu	Hg	Ni	Zn
Germany	Clay	1.5	100	100	60	1	70	200
	Silt	1	70	60	40	0.5	50	150
	Sand	0.4	40	30	20	0.1	15	60
Holland[b]		0.4 +0.007(T+3H)	50+T+H	50+2T	15+0.6(T+H)	0.2+0.0017 * (2T+H)	10+T	50+1.5(2T+H)
Italy		1.0	50	50	75	1.0	50	150
Switz[c].		0.03	1.0	—	0.7	—	0.2	0.5
Canada		4	100	**	**	1	36	370

a.Source: German Ministry of Environment (1998); Canadian Council of Ministers of Environment (1998)
b.Source: Bavnick (1989) Key: T = Clay%; H = Humus%
c.with HNO_3 0.1M extract after (Häni, 1989); see also: Berset (1993) ** Canada Fertilizers Act covers these elements.

New Directions in Metal Standards

As mentioned, several countries are in the process of either further reducing metals, or have created more than one compost class. The concept is that the highest Class (e.g. Type A or AA) would represent preferred composts for intensive horticultural uses. Table 10 shows the projected changes (Bidlingmeier & Barth, 1994).

Table 10: Alternative Heavy Metal Limits

Programs or Countries with Proposed New or Reduced Concentration Limits for Metals

Element	EEC Organic Rule §	EU-Eco-Label fl	B Agr	NL*	NL**	CH	UK ˛	Notes
Arsenic	-	-	-	25	15	-		§ EEC Organic Rule #2092/91 Brussels
Boron	-	-	-	-	-	-		
Cadmium	0.7	1.0	1	1	0.7	3	1.5	* Quality Class A ** Class B
Chromium	70	50	70	50	50	150	100	fl EU- Eco-Label ˛ UK Compost Association (CAS2)
Cobalt	-	-	-	-	-	-	-	
Copper	70	100	90	60	25	150	200	for country codes see previous table
Lead	45	100	120	100	65	150	150	
Mercury	0.4	1.0	1	0.3	0.2	3	1	
Nickel	25	505	20	20	10	50	50	
Selenium	-	-	-	-	-	-	-	
Zinc	200	200	280	200	75	500	400	

The distinction of two classes of compost has also been supported by the British Soil Association and is implied in the Canadian BNQ and CCME standards (CCC, 1999). It is also essentially similar to the established EEC-Organic rule as well as the EU Eco-Label for Soil Improvers which sets low levels allowed for metals in general (OJ, 1998). The Eco-Label program also now sets required limits for Mo, Se, As, and F if MSW or industrial wastes are present in compost source materials. Overall, the approach is a logical idea since generous standards developed for sludges were never anticipated for materials applied as heavily as horticultural grade composts, as also indicated by Berret and Holzers comprehensive study of Swiss soils (1993). A recent overview including modeling of soil contamination partitioning effects attributable to sludge, compost, chemical fertilizers and other wastes is provided by Hackenberg and Wegener (1999).

OTHER PARAMETERS FOR COMPOST STANDARDS

Physical Composition Of Composts

The acceptable quantities of foreign matter in compost has been a subject of some debate, but generally there is greater agreement on these standards. Normally, stones are distinguished from non-decomposable “foreign matter” which includes glass, plastic and metal. The limits pertain to a percentage at a specific screen size. The following table summarizes physical standards of countries that regulate compost. (Table 11):

Table 11: Maximum Foreign Matter Particles Allowed in Composts in Various National Standards

Country with standard	**Stones** % of dry weight	**Man-Made Foreign Matter** glass, plastic, metal, as% of dry weight
Australia	must be < 5% of >5mm size	< 0.5% for >2mm fraction
Austria	must be < 3% of > 11 mm size	< 2% of > 2mm fraction
Belgium	< 2%	no visible contaminant, max 0.5% > 2mm
France	—	Max. Contamination 20%; < 6% of > 5mm fraction
Germany	must be < 5% of > 5mm size	< 0.5% for >2mm fraction
Italy	—	< 3% total
Netherlands	must be < 3% of < 5mm size	< 0.5% for >2mm fraction
Spain	—	“free of contamination”
Switzerland	must be < 5% of > 5mm size	< 0.5% for >2mm fraction; max 0.1% plastic
United Kingdom	< 5% > 2mm	< 1% > 2mm < 0.5% if plastic

Testing Frequency for Compost Facilities

Sampling size and frequency has been examined by many countries. Both the quantity of a batch and the particle size or coarseness of the compost affect recommendations. The following table (Table 12) provides indications on how various countries have regulated sampling and testing frequency for compost products.

Table 12: Testing Frequency for Compost Quality Analyses

Country	Compost Testing Frequency Recommended
Germany	< 2000 t/a; 4x / quarter > 12000 t 12x 8 times/yr. (t/a = tons/annum)
Netherlands	1 time each 5000 tons or min 6x per year
Belgium	8 times/yr for 4000-10000 ton/yr facilities
Austria	1x / year minimum or 1x per each 2000m^3
Switzerland	1x/year for > 100 tons
France	1x every 6 months
Italy	unregulated
Spain	unregulated
Denmark	1x every 6 months
United Kingdom+	2x < 5,000 tons 3x > 5000 t 4x > 20000 t

Sampling Methods to Control Variability (BGK, 1992, Mullet 1992; S-SEPA, 1997)		
Particle Size of Compost	Agitated Compost	Non-agitated Compost
Coarseness is < 20mm (< 3/4")	< 50 tons take 5 samples	< 150 tons 1 sample per 10 tons
	> 50 tons 1 sample each 10 t	>150 tons 10 samples total
Coarseness is > 20mm	< 50 tons 10 samples	< 150 tons 1 per 5t
	> 50 tons 1 sample each 5 tons	>150 tons 15 samples
	Minimum sample quantity	
< 20 mm	3 liters (0.8 gal)	
> 20 mm	5 liters (1.3 gal)	

Sampling Consistency for Laboratory Analysis

Among the greatest challenges with compost quality testing is sample consistency, both in the field and in the lab. All compost quality standards make the assumption that uniform and reproducible sampling and analytical methods are being used. A Northeast investigation of test methods found large variation within the lab depending on how a sample was prepared prior to analysis (*unpublished report*, UVM, 1999). When 6 samples were separated into 3 fractions prior to lab analysis the coefficient of variation of test results for total-C and C:N ratio varied from 7 to 46% and averaged 30%. Thus, accuracy and precision are significantly influenced by sample preparation protocol and inherent homogeneity of material (TMECC, 2001). With regard to accuracy, one must ask: how does the handling procedure affect how meaningful the test data are? With regard to precision, the question is: does the handling method improve or worsen reproducibility of the test data? It may be acceptable to show that tests results based on a specific handling method are accurate without being precise. To over-emphasize precision, however, when accuracy is questionable is the greatest pit-fall in laboratory work. This is especially the case in measuring such common traits in compost as C:N, especially when it can be shown that sample prep techniques significantly influence accuracy.

A primary issue with consistency of analytical results concerns pre-treatment in the form of sieving, drying and grinding. While it is standard that many labs will screen out fractions >10mm prior to analysis, there is no fixed rule, and some of the national programs reviewed herein include recommendations *not to screen* for certain types of tests, especially biological tests. Thus, several of the sampling and testing programs we review herein have different handling and pre-treatment methods for a single compost sample, *depending on the parameter being measured*. In Germany, for example, respiration, salt content and soluble plant nutrients, among other traits, are tested on sieved fractions while metals, organic matter and total-nitrogen are tested on the entire sample after drying and grinding.

Since compost is non-homogenous with regard to particle density as well as particle size, and also susceptibility to drying affecting chemical traits, these initial prep methods have a potentially large effect on analysis results. It is primarily important to qualify pre-screening. The over-size portion discarded as inerts must however be reported as it biases the data for compost per volume as experienced in the field.

Hygiene and Hazard Standards

Each country varies in its view of required compost hygiene. Hygiene standards which are both stricter and more lenient than the EPA CFR40 Chap 503 limits can be found. The following section sets out some of the primary differences in how compost as a hygiene product is viewed.

A Warning Standard: The Australia System

Compost may be viewed as a potential source of harmful dust and live organisms. Therefore, some countries have considered a cautionary process or warning system for commercial products. Specifically, the Australian Standards Committee has officially recommended a warning label be “conspicuously displayed” on compost products (AU-99)

:

Figure 2.
The Australian Rule
for Hazard Declaration
of Compost Products
(AS-1999)

11 AS 4454—199

HAZARDOUS

COMPOSTS, POTTING MIXES,
AND OTHER ORGANIC GARDENING MATERIALS

This product is made from organic materials, including composted pinebark, and contains living microorganisms, including bacteria, fungi and protozoa. May also contain mineral and fertiliser additives.

RISK	Inhalation of dust and/or liquid mists may irritate, inflame or sensitise the nose, throat and lungs resulting in illnesses ranging from hayfever or asthma, to pneumonia (e.g. Legionnaire's disease) or pneumonia-like illnesses. Direct contact with this material or its dust and/or liquid mists (bioaerosols) may cause skin irritation (dermatitis), and skin or eye infection or irritation. People particularly at risk are those suffering from asthma or allergies, and those whose immune defence systems are compromised.
SAFETY	Avoid contact with eyes and skin. Avoid breathing dust and/or liquid mists (bioaerosols). Wear suitable protective clothing and standard duty gloves (AS/NZS 2161.2). If exposed to dust and/or liquid mists, also wear dust resistant eye protection (AS/NZS 1336) and particulate respirator (AS/NZS 1715 and 1716). Wash thoroughly immediately after handling. Wash work clothes regularly. Clean up by wet sweeping or vacuuming. Store this product in a cool location.
FIRST AID	Irrigate eyes with plenty of water for 10 minutes. Wash skin with soap and water. Seek medical attention for any persistent skin, eye or respiratory symptoms.
DISPOSAL	Follow above safety precautions and collect in containers for disposal as trade waste in accordance with local authority guidelines.
MANUFACTURER	xxxx

For further information, refer to the Material Safety Data Sheet for this product which is available from xxx.

A warning of this nature is likely to be viewed as a deterrent in the marketplace. However, it also defines a liability net that is useful under certain circumstances.

Hygiene as Pathogen Reduction

America has championed the concept of "pathogen reduction", and established units of reduction and test methods to ascertain it in the Chap 503 rule (EPA 1989). This rule allowed for three classes of pathogen reduction (A, B, C) which gave greater latitude in pathogen compliance than previous Chap 257 Rules. It also tightened pathogen rules for all classes by 1) removing the allowance that a 2-log-reduction of pathogens is adequate and 2) requiring bacteria tests *just prior to* final application or sale. This latter provision is intended to take into account the potential for pathogen re-growth and eliminates earlier specific log reduction computations when pathogens may be high to start with. The final rule views fecal *coliform* and *Salmonella* as equivalent tests, based on correlation studies. The EPA 503 rule has been widely adopted as a *de facto* compost standard, regardless of presence of biosolids.

US guidelines and standards, while specific, do not appear more definitive than those from other western countries, and in some cases less so. A range of views and regulatory guidelines are seen regarding necessary hygiene from compost operations and products. Differences are found with regard to test organisms and length of time at elevated temperatures. Furthermore, certain confusion may be created in the EPA's use of the definition "Exceptional Quality (EQ) sludge" which meets Class A standards with regard to pathogen content and ceiling metals (EPA-1993,1999). This classification restricts "quality" and circumvents priority-pollutant and dioxin limits. Like many other guidelines and standards it is silent regarding performance traits: e.g. phyto-toxicity, nutrients or other potentially important agronomic traits. Use of this classification by biosolids composters to imply a product meets a high standard can be misleading.

The following table (Table 13) summarizes temperature and time requirements and testing guidelines for compost products:

Table 13: Selected Compost Hygiene Standards

Country	Compost Method	Temperature / Pathogens
Australia	All methods	> 55C for atleast 3 days; allowance for variation and lower temperatures
Germany	Open Windrow Closed/ In-Vessel PLUS All New Facilities: no presence in 25 g of: No-survival of added:	> 55C 2 weeks or > 65C for 1 week >60C for 1 week Human/Veterinary Hygiene: S. senftenberg W775 Phyto-hygiene: Tobacco-mosaic Virus (TMV) & Plasmodiophora brassicae
Austria	all composts	> 60 C 6 days or > 65C 3 days, or >65C 2 x 3 days
Switzerland		> 55C for 3 weeks, or > 60C for 1 week, or proven time temperature relationship
Denmark	all composts	> 55C for 2 weeks

Germany has extended the concept of hygiene in compost by distinguishing human/animal from phyto-hygiene. In the latter category, all new compost facilities must demonstrate kill potential for tobacco mosaic virus (TMV) and club-root disease caused by *Plasmodiophora brassicae* (see table 13) (Prause et al., 1995). This is a procedure similar to PFRP equivalency in the United States. Switzerland has determined recently that there is unsatisfactory control over compost hygiene (Candinas et al., 1999).

Hygiene as Worker Safety

There are few hygiene standards evident for worker safety at compost or organic recycling plants. However, a body of new evidence from international studies suggest that a number of areas of concern exist for airborne contaminants within compost plants. These include allergic alveolitis (EAA), Organic Toxic Dust Syndrome (OTDS), respiration allergies from inhaled spores; dermal, pulmonary and systemic infections and contact allergies (Böhm et al. 2000). It is rare to see a compost plant in Europe that does not have negative air and vacuum air hoods over bio-waste sorting conveyors; in America, most workers are unprotected. It may be predicted with certainty that considerable new developments will take place in this area.

New Areas: PTE's (Potentially Toxic Elements

The concept of contamination has been extended to include potentially toxic elements or PTE's. This is evident in national literature (e.g. Denmark, Sweden) and international (e.g. EU-Sludge Rule, 2000). PTE's are defined as all the standard EPA 10 heavy metals, including molybdenum (Mo) and fluorine (F) as well as several groups of organic constituents, notably softeners such as phthalates (DEHP and DBP) and surfactants (LAS), among others. New efforts are underway to reduce nonylphenol(+etholyates) (NPE) which occur in cleansing products. Several countries are considering rules for PTE's specific to composts (SEPA2, 1999) - (see Table 14).

Table 14: EU Limit Values for Land Application of Potentially Toxic Elements in Organic Waste[a]

Compounds	Limit Values mg/kg/TS	Values observed in Composts[b]
AOX Absorbable organic halogens	500	90 - 120
LAS Linear alkylbenzene sulphonates	2600	< 21
DEHP - Di(2-ethylhexyl) phthalates DBP - Di-n-butylphthalate	100 -	1,200 130 - 2,000
NPE nonylphenolethoxylates	50 - 100	10 - 2,000
PAH polycyclic aromatic hydrocarbons	6	16 - 4,100
PCB polychlorinated biphenols	0.8	7 - 170
PCDD/F	100 ng TE/kg	2 - 56

a.Source: European Commission, Sludge Working Document Brussels, April 2000 b.Source: Organic Pollutants in Compost, in: SEPA (1997)

Pesticide / Herbicide Content

There is considerable interest in pesticide and especially herbicide residue content of organic wastes. Surveys have shown considerable variation in pesticide residue contents, dependent on the source, time of year and the fraction collected. One recent study has shown that composts containing high contents of flowers either from nurseries or imported cut-flowers may contain elevated levels of insecticidal and fungicidal pesticides and their metabolic by-products, including some not permitted in the western countries (Vorkamp, et al. 1997). Much is known about the behavior of pesticides in the environment; however, relatively little is known of the content and composition of pesticides in wastes and composts. Pesticides of concern which have been frequently detected in composts include: carbaryl, atrazine, chlordane, 2.4-D, dieldrin, chlorpyrifos, diazinon, malathion, and others (SEPA, 1997). More recently, degradation-resistant herbicides have been identified as a source of plant phytotoxicity of composts, even at levels considered by EPA to be acceptable in the environment (Bezdicek et al. 1999).

Nitrogen Immobilization Potential

In certain countries where compost has become a more significant agricultural commodity, testing for N-immobilization potential is recommended. In Switzerland, poor N-performance of composts has been reported to be the primary compost quality deterrent (Heller, H. *personal communication*, 1998). Nitrogen immobilization or tie-up occurs were the C:N ratio of the compost is sufficiently high to require soil microorganisms to consume excess soil soluble nitrogen to assist in the further decay. This immobilization of available-N can harm agricultural crop yields. The Australian Standards group has published a test procedure for “nitrogen draw-down” (AU-99), having discarded the C:N ratio test as un-satisfactory to indicate immobilization potential. The test employs addition of soluble-N and measures “draw-down” from 4-day incubation at 25C. The German BGK lists N-immobilization as a known feature of products receiving its Seal of Quality, yet the methods handbook does not describe a procedure (BGK, 1994). Several common agronomic methods do exist to determine N-immobilization.

Weed Content

At least 4 countries have written or implied weed standards in compost: Holland, Germany, Australia and the United Kingdom. Holland has a limit of 2 weeds/liter (DHV, 1999). Germany has a limit of 1 weed per 2 liters and considers compost heavily contaminated when more than 4 weeds are found in 2 liters. The United Kingdom limit is 5 weeds/liter (CAS2, 2000). The German test requires 3 liters of compost for the test; this can be a cost and space constraint for many laboratories. Woods End has arbitrarily set a limit of less than 5 weeds/liter for agricultural composts. Australia states “no weed propagules” for composts, but does not give a method. A proposed method by the Compost Council has a sensitivity of 3 or more weeds per liter (TMECC, 2000).

Salt Content

Salts in the form of mineral ions are naturally present in all composts and normally concentrate somewhat during composting. Salt may pose limitations for soil application, since plants have varying sensitivities. There is little agreement on how to classify salts in composts and what, if any, limits should be set. Australia's new compost standards impose a salt imitation for soil application, as follows:

Table 15: Maximum Compost Application Based on Salt Content[a]

EC of Compost	rate for sensitive plants	rate for tolerant plants
	liters / m^2 (gal / 100 ft.^{2})	
0 - 1	unlimited	unlimited
1 - 2	< 15 (37)	< 60 (150)
2 - 4	< 8 (20)	< 32 (78)
4 - 8	< 4 (10)	< 16 (39)
8 - 12	< 2.5 (6)	< 10 (24)
> 12	< 2 (5)	< 8 (20)

a.Modified after Australia Standards, AS 4454-1999 based on rates mixed into the top 5cm (2”) of soil.

Plant Phytotoxicity Tests

There are a variety of compost phytotoxicity tests which have been proposed and published for quality monitoring. Many fall under the classification of “biomaturity” testing (Mathur et al.,1993) where a mixture of chemical and biological tests are used. The various plant based tests rely either on a mixture of compost with soil or peat (Germany) or 100% compost using garden cress, barley or radish seeds. Australia requires compost be leached prior to the test, presumably to remove salts and eliminate the need for media dilution; however, for product sold as a potting mix, no leaching is employed. In Switzerland, straight (100%) compost is used and an additional test called the “closed cress test” is applied; this distinguishes gaseous phytotoxicity in addition to compost-borne toxicity (Fuchs, 1996). Austria recommends a test with a range of compost/ peat dilutions (Amlinger, 1995).

While compost producers are evidently opposed to the indiscriminate use of laboratory plant assays, largely because of the concern for interpretation, some compost researchers are calling for sharpened test methods to distinguish “high quality compost” from “low-value composts” (Fuchs, 1996). Table 16 summarizes published or standardized national tests.

Table 16: Plan Growth Performance Standards

Test Parameter	German	Swiss	Austrian	Australian
Plant Growth Test	25% and 50% compost in standard soil media; Barley seeds or Cress seeds must pass > 90% in Barley test	100% compost open and closed cress test; no pass/fail levels	0-100% compost blend with peat; cress and barley seeds; must pass >80%	100% *Leached* compost; radish Seeds; must pass at > 60% of reference
Plant-Use	Compost must be tested for the actual use recommended on the bag	n/a	recommended tests in actual media	2 use categories with specific limits for agriculture or gardening

It is very likely that considerable new developments will take place with regard to plant growth tests as a measure of compost quality and maturity.

Compost Quality for Substrates

Two countries have recommended nutrient or quality levels for use of compost in plant substrates: (e.g. potting mixes), among several other uses. Such recommendations come very close to an end-use quality certification program. Woods End's values are shown for comparison when approving a product if it meets criteria specific for an identified use (Woods End, 2000). This is an area where voluntary standards may have a role to play.

Table 17: End-Use Test Values Recommended for Compost: Category Potting Mixes[a]

Test Parameter	German	Austrian	WERL (USA)
Salt	< 2.5 g/liter	< 2 g/liter	< 2 mmhos/cm
Avail-N	< 300 mg/l	< 800 mg/l	100 - 300 mg/l
Phosphate	< 1,200 mg/l	< 800 mg/l	800 - 2500 mg/l
Potassium	< 2,000	<1,500 mg/l	500 - 2000 mg/l
Maturity	Dewar V	pass plant test	Solvita 7-8
Organic Matter%	> 15	> 20	> 30
pH	declared	5.5 - 7.0	6 - 7
Foreign Matter	max 0.5% > 2mm	max 0.5% > 2mm	< 1% > 2mm

a.Assuming 40-50% of mix (v/v) is compost: Sources: Wiemer& Kern (1994); Fröhlich et al. (1993)

Compost Declaration Systems (Swedish & Danish EPA examples)

The recent (Dec 99) report by the Swedish EPA (SEPA) has introduced a required compost declaration system that forms the basis for product compliance and marketing. The earlier Danish form of this declaration is shown in the addendum. The concept of these new reporting systems is that each compost product should be accompanied by a fairly comprehensive description of qualities and properties (see Appendix).

COMPOST MINIMUM STANDARDS IN THE UNITED STATES

Several states have adopted guidelines or rules for compost quality. These rules are distinct from EPA biosolids rules or state requirements for compost facility siting. Minimum limits for stability and physical qualities are used in order to comply with procurement programs. The following table identifies these states and the relevant agency.

Current States	Organization	Nature of Regulation	E-Mail/Regulation Link
California	Caltran	Transportation Dept requires min. quality for use of compost	john_haynes@dot.ca.gov
Connecticut	CT-DOT	Dept Transportation purchases	donald.larsen@po.state.ct.us
Idaho	IDOT	Dept Transportation purchases	n/a
Illinois	IL-EPA	General Use	www.ipcb.state.il.us/title35/g830.htm
Maine	ME-DOE	General Use	www.state.me.us/sos/cec/rcn/apa/06/chaps06.htm
Massachusetts	Mass-Highway	DRAFT Rule : Dept Transportation purchases	n/a
Minnesota	MN-PCA	General Use	www.revisor.leg.state.mn.us/arule/7035/2836.html
New Mexico	NM MMR	Bureau of Mines requires for land reclamation composts	n/a
New Jersey	NJ-DEP	General Use	www.state.nj.us/dep/dshw/recycle/regs/njac726a.htm
Texas	TX-DOT	Dept Transportation purchases	bcogburn@mailgw.dot.state.tx.us
Utah	UDOT	Dept Transportation purchases	n/a
Washington	WA-DOT	Dept Transportation purchases	www.wsdot.wa.gov/eesc/cae/pse/gsps/02021mr8.pdf

In the specific area of stability or maturity of compost, some regulations do exist under state procurement programs in CA,CT,NJ,WA,TX,NM,MN,OH, ME. The most common parameter used for maturity is self-heating (Dewar Test) followed by oxygen-demand or CO_2-respiration. All states that apply a maturity definitions also accept the Solvita test as an equivalent procedure.

COMPOST MATURITY STANDARDS IN US

Compost maturity is beginning to be more recognized as a significant parameter to evaluate compost. The reason is that immature and poorly stabilized composts pose known problems during storage, marketing and use. In storage, immature composts may become anaerobic which often leads to odors and/or the development of toxic compounds, as well as bag swelling and bursting. Immature composts may heat up in pallets during shipment. Continued active decomposition when these composts are added to soil or growth media may have negative impacts on plant growth due to reduced oxygen in the soil-root zone, reduced available nitrogen, or the presence of phytotoxic compounds. 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.

In a new development of the California Compost Quality Council (CCQC) in conjunction with Woods End Laboratory and other peer-reviewers, maturity has been defined as <u>the degree of completeness of composting</u>. In contrast to earlier definitions used in America, maturity thus is no longer viewed as a single property that can be singly tested for. Therefore, maturity must be assessed by measuring *two or more parameters* of compost. In the CCQC process, these parameters can be selected from a list comprising two dissimilar groups of tests. This new approach also recognizes that appropriate laboratory tests must be demonstrably reliable for evaluation of composts produced from many types of wastes.

As reflected in the opening statement from the Worldwatch Institute, compost producers and users must realize that the presently accepted methods to evaluate stability and maturity may not completely or precisely address the most important concern: ‘Is [the product] appropriate for and does it perform well in the particular end-use’. Thus, the use of final plant growth tests is encouraged.

The Maturity Index: A Composite of Two or More Parameters

A mature compost should be considered to possess characteristics of completeness in the composting process and show minimal potential for negative impacts on plant development, the latter being carefully defined. As maturity is not described by a single property- according to the new definitions emerging out of the CCQC process- the maturity index is based on “passing” two or more specific tests, drawn from two lists of parameters. This system will hopefully provide the greatest assurance to the producer and end-user that the product is being correctly assessed.

In the new definition of Maturity Index a two-tiered system is applied beginning with the minimum characterization of the C:N ratio and then proceeding to description of at least one parameter from each of the two dissimilar Groups (“A and B lists”). In the proposed system, each of the tests is interpreted by comparison to a stability index specific to each method (see Table 18 and 19). Compost samples must first pass the C:N ratio standard (“< 25”) prior to consideration of results from tests in Group A and B. The CN screen is applied loosely as CN is felt to be a poor indicator alone of maturity or stability.

Another new development is that the proposed system recognizes three levels of maturity: two acceptable levels and one non-acceptable. The results of Group A and B tests will determine compost to be one of these three levels defined as 1) very mature, 2) mature or 3) immature and unacceptable, as follows (see Table 19).

Table 18: Proposed Compost Parameters Tier System to Determine Maturity Index[a]

Carbon Nitrogen Ratio (C:N) [b]	
Group A	**Group B**
Carbon Dioxide Evolution or Respiration: includes O_2 CO_2 and Solvita Oxygen Demand Dewar Self Heating Test	Ammonium:Nitrate Ratio Ammonia concentration Volatile Organic Acids concentration Plant test Volatile Solids Reduction

a.CCQC Peer-review System; Woods End Lab document
b.C:N must be < 25 to proceed with test

Table 19: Proposed Three Tier System to Classify Compost Maturity

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

Group A Maturity Index Methods

Currently there are a number of tests available to determine compost maturity or stability. Many of these methods are covered in the German Test Methods (BGK,1994), or the Australian Manual (AS-99, 1999). In America these and other newer methods may be found in the soon-to-be released Test Methods for the Examination of Composting and Compost Products by the US. Composting Council (TMECC, 1999). Other methods have been developed by commercial laboratories. They include:

Oxygen Uptake Rate

Carbon Dioxide Evolution Rate

Dewar Self-Heating Test

Solvita® Test

Although oxygen consumption and carbon dioxide generation or evolution are related, the measurements are not consistently equivalent. The Dewar self-heating test integrates a number of factors and provides a “holistic” evaluation of compost that may correlate well to field observations especially as regards heating of the composting process. In comparison to the methods based on respirometry the Dewar method is relatively simple and provides data that is easy to understand, as units of heat. The Solvita® test is a unified system that estimates respiration and ammonia by a color forming chemical reaction.

Dewar Self-Heating Test (Bungesgütegemeinschaft Kompost, Germany)

The Self-Heating test uses a standardized steel container that holds approximately 1 liters of compost (Jourdan, 1988). Essentially the method has not been changed since 1988. As with any test, the compost sample moisture content may need to be adjusted prior to incubation. A maximum-minimum thermometer is then inserted to about 5 cm of the bottom of the container. which is left to stand at room temperature for a period of at least 5 days and no more than 10. The highest temperature of the compost sample is recorded daily. The results are calculated as maximum temperature rise during the test period. The Dewar test is limited in the sense that it mostly distinguishes only very mature from very immature; few grades in-between are seen (Woods End, 1995).

Solvita® Test

The Solvita test is a color-coded test procedure to determine maturity index based on a two-tiered test system using respirometry and ammonia gas emission. As with other methods, 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 as opposed to weight of a subsample is added to a test incubation jar. If the sample has been adjusted (adding water or drying) then it is allowed to equilibrate for up to 72 hours prior to the test. Following the equilibration period a specially treated ‘gel paddle’ is placed in the test jar and after 4 hours the color development on the gel surface is visually compared to a pre-calibrated coded color chart. Two gel results indicate CO2 and NH3 concentrations. The Sovita test is listed by 13 states and is an official method in Sweden, Denmark, Spain and Norway.

Limitations of Respiration Based Methods

Compost samples that have non-normal moisture content may be biologically impaired; either low moisture reducing respiration of high-moisture increasing anaerobic conditions. This was a large problem when the Dewar method was first introduced in Europe, and moisture levels tended to be too low for the test, giving some erroneous results (BGK, 1994). A standard adjusted moisture content should be used for all samples to reach the ideal biological optimum-defined which is 60-80% of the *water holding capacity*. Dried or cold-stored samples may trigger temporarily high biological activity following warming or moisture re-adjustment. Therefore a pre-incubation or equilibration of each sample should be employed to assure accurate measurements of respiration activity. This can be empirically determined on a case by case basis and is generally agreed to be 1-3 days.

Interpretation of Group A Parameters

Table 20 provides proposed interpretative values for Very Mature, Mature and Immature Composts based on each of the CCQC Group A tests. Different values for methods based on respirometry reflect differences in the method of calculation (units) or conditions of the test.

Table 20: Maturity indices for Group A (stability) methods

Method	Units Rating		
	Very Mature	**Mature**	**Immature**
Oxygen Uptake *O_2 / VS / hr*	< 0.5	0.5 - 1.5	> 1.5
CO_2 *C / unit VS / day*	< 2	2 - 8	> 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 (^oC)*	< 10	10 - 20	> 20
Solvita *Index value*	7 – 8	5 - 6	< 5

Group B Maturity Indices:

The presence of compounds toxic to plants (phytotoxic) is a common problem associated with immature composts. Such composts may contain ammonia and/or inorganic or organic compounds that may reduce seed germination and impair root development. Germination is often not affected as much as root development, making germination tests very poor indicators of compost quality. 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, butyric) can be generated. However, with time in a typical aerobic process, these materials will undergo biological conversion to non-phytotoxic compounds.

The premise for using soluble nitrogen for maturity indicators is that during early stages of composting very little if any nitrate-N is formed. As the thermophilic stage is passed, the mesophillic microorganisms that convert organic N to ammonium- and nitrate-N begin to flourish. The appearance of significant quantities of nitrate-N is an indicator of a maturing compost. Normally, in mature composts the nitrate-N levels exceed the levels of ammonium-N by several factors. Therefore, determination of ammonium- to nitrate-N ratios is a useful parameter to assess degree 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. However, by nature of the definition, plant assays may indicate either none or any one or more of the factors grouped generally under “phytotoxic”. Test results are dependent on preparation of the media especially in regards to concentration or blending of compost with other ingredients. Thus, any method used to evaluate potential phytotoxicity should reference the plant and concentration of compost used.

Interpretation of Group B-List Parameters

Table 21 gives suggested interpretative values for very mature, mature and immature composts based on each of the Group B tests.

Table 21: Maturity Indices for Group B methods

Method	Units Rating		
	Very Mature	**Mature**	**Immature**
NH_4- : NO_3-N Ratio [a]	< 0.5	0.5 - 3.0	> 3
Total NH_3-N *ppm, dry basis*	< 75	75 - 500	> 500
VOA *ppm, dry basis*	< 200	200 - 100	> 1,000
Seed Germination *% of control*	> 90	80 - 90	< 80
Plant Trials *% of control*	> 90	80 - 90	< 80
Nitrogen Draw-down [b]	0	< 10%	> 25%

a. If both levels of NH4 or NO3 are very low in compost (i.e. less than 75 ppm) this ratio has little value.
b.Not a CCQC parameter

CONFORMITY vs. DISAGREEMENT IN EXISTING STANDARDS

Compost quality assessment has gradually evolved differently in various parts of the world as political and industrial developments have taken place. Surprisingly, there are a number areas of seeming close agreement across national boundaries. Not surprising are the areas of difference.

One approach to choosing viable standards is take the path of least resistance: formulate a set of criteria which reflect where general agreement is readily apparent; then identify areas where disagreement or weakness in approach is evident. Where moderate to significant steps are needed to reach a general accord, it may be best to allow voluntary standards to be used instead pending further research.

The following table (Table 22) attempts to group the methods and indicate the nature of similarity/ dissimilarity between countries and steps to common acceptance.

Table 22: Compost Quality Traits and Agreement between Countries

Compost Quality Category	Level of agreement between various countries	Change needed to reach general accord
Heavy Metals	USA discordant in regards all other countries	Significant: Adopt two levels - Class I (low metals) and Class II (elevated metals) - or- - abandon EPA503 rule
Physical Description	little data on test frequency	Moderate: determine ranges
Density and Porosity	few developed standards	None: support voluntary reporting of traits
Stones vs. plastic and other inerts as % of fry matter	generally good agreement	None: adopt description scheme with set limits
Hygiene:		
Facility / Worker	Poor - some countries very low standards	Significant: adopt research framework
Plant - Phyto	Germany alone with plant hygiene standards	None: support voluntary reporting where needed
Potential mammalian pathogens	Good agreement re: Salmonella & coliform	None: adopt description scheme with set limits
Plant Growth	Generally good; weak development of methods	Moderate: support research & voluntary reporting of performance;
Weeds	incomplete methods; contamination not defined adequately	Moderate: evaluate methods and determine “clean” level
Maturity / Stability	Generally good; many methods at research level need development	Moderate: more methods need to be recognized and correlated

The information in this table show clearly tremendous difference in view between the US and Europe with regard to metals. From it, it may be doubted as to whether agreement will ever exist in this area. Counter to some views within the U.S., Americans need to recognize that the European standards are excellent scientific tools to identify sources of metal contamination and to evaluate cleanliness of source separation programs. They were designed scientifically based on this. The European soil background values are very valuable for assessing conditions of agricultural soils. These published European limits may be successfully employed to spot abnormal compost samples or soil conditions requiring some attention. It should be added that virtually all farm-based composts and source separated organic wastes potentially can pass the strict EU rules. In contrast, the EPA 503 standards for metals are simply biosolid standards - use of them with regard to any other compost is likely to obscure and not illuminate important issues regarding quality.

SUMMARY

This report gives a brief overview of the evolution of compost quality standards during the past 20 years and suggests some new promising directions, especially one regarding classification of maturity coming out of the California peer-group (CCQC) process[1]. Most of all, this report underscores the many contrasts evident from the variety and range of standards that do exist across several countries. Contrary to the views of those who seek fixed numbers on which to regulate, the evolving understanding of compost quality if anything reveals that social and marketing forces - which themselves are changing- must continue to play an important role.

This report distances itself from any position that there are absolute standards that need to be applied to composts. Rather, it is evident particularly in examining European accomplishments, that a scientific and political consensus can emerge that make otherwise unusual standards very successful. This is the case, for example, with Germany, the country with the most composting per capita worldwide, where the Dewar test is the standard for maturity even though alone as a specific test it is not particularly convenient or accurate. Ironically, Woods End's and some British and Scandinavian scientific studies showing the two-scale limitations of the Dewar test have met with strong opposition there (supporting the view that standards are partly social and political).

Nothing illustrates clearer the often chaotic relationship of social and political forces than the comparison of compost heavy metal standards between America and the rest-of-the-world. As already noted in this report, American standards bear no relationship to other national standards viewed either in terms of concentrations of permissible metals or either annual and/or maximum loading rates to soils. The EPA, with USDA support, introduced the 503-rule at a time when concern for land application of sludge needed to be re-focused by a "risk view" on the industry. The imperfect nature of the science of risk-analysis has always been recognized. However, the current extrapolation of the 503 approach well outside the sludge realm to composts in general, and

1.The CCQC process involved the CA Integrated Waste management Board (CIWMB) along with Woods End Lab, Soil-Control Lab, Soil&Plant Lab and other advisers.

now fertilizers and soil, is certainly somewhat illogical and possibly harmful. This is especially the case when we recognize the tremendous body of scientific data that exists regarding heavy metals in soils and organic wastes, which Europeans have made extensive use of in designing standards that are realistic and achievable,- as shown in this report- while protecting the highest quality of the land. Unfortunately when some American spokespersons advocate that they have the best scientific approach- thereby elevating risk analysis beyond what it is known to be useful for- they inadvertently promote discord and disharmony in the international scene.

Based on this view, this study advocates that Americans (and other countries) begin to use the European metal scientific data as a guideline for what is possible in well managed source separated or agricultural compost programs. It may be hoped from this use of the data that atleast composting programs and end-use quality will thereby be improved. On the other hand, the Europeans have less to offer when it comes to maturity standards where very little research and development has taken place since adoption of the Dewar test for stability (good evidence that the adoption of strict standards impede scientific progress). Indeed, Germany with its nearly 10-million tons/year biowaste compost program presently has a political crisis in how to get rid of all the product- in many cases. composters and regulators have virtually abandoned any representation of maturity with compost routinely distributed at Dewar grade III stability, in order to just get it out onto farm fields, where anyway immature compost poses few risks (Peterson & Zimmer, 1996). In Switzerland the abundance of low nutrient bio-waste composts which immobilize nitrogen is presenting its own challenges (Heller, 1998). In all countries, compost hygiene is of ever increasing concern. For the American scene, maturity and end-use guidelines are likely to be the most important focus for standards since compost marketing for high-end uses is growing. Taking into account the scientific data and the political and cultural trends, it is likely that we will see many more years of innovation and worthwhile developments in composting.

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APPENDIX

The Danish EPA Compost Declaration System

Appendix Page 1: The Danish EPA compost declaration scheme

[write the name of the product/composting plant and period of validity]
Compost declaration as in EPA-report no. 470-1999

Compost
Organic soil improver made of:
: weight-%
: weight-%
: weight-%
: weight-%
Additives: kg per ton input

Place of production

Product responsible

About the use of compost

- A good, slow release organic fertiliser with long lasting effect
- Improves the capability of the top soil to contain nutrients
- Make clay rich soils more workable
- Reduces the need for irrigation in sandy soils
- Uniform and attractive mulch (soil cover) in beds or under bushes and trees
- Exceptional lawn topdressing when mixed with sand
- A growing medium for indoor and greenhouse plants when mixed with peat

Get separate user guides: Private garden owners, Landscape gardeners
Farmers, or Christmas tree and fruit growers

Nutrients in marketable compost

	kg/m^3	kg/tonne
Total nitrogen		
Ammonia-nitrogen		
Nitrate-nitrogen		
Available nitrogen 1. yr.		
Total phosphorous		
Total potassium		
Total magnesium		
Total sulphur		

Electric conductivity .... mS/cm (interval)

pH .... (no unit)
(EC and pH are both stated in two traditional ways: one meant for farmers, another meant for greenhouse growers)

Soil improving properties
besides the supply of micro-organisms

Liming effect, as	kg lime / m^3
- " -	kg lime / tonne
Organic matter (loss on ignition)	% of dry matter
CEC (cation exchange capacity)	meq / 100g dry matter

Physical properties

Applied sieve	mm
Dry matter	%
Volume weight (at the mentioned dry matter percentage)	tonne / m^3
All particles under 5 mm	% of dry matter
Stones above 5 mm	% of dry matter

Sample taking and quality control
Samples are taken according to the directions from The Plant Directorate. The procedure for the internal quality control and the analysis reports from the external laboratory can be forwarded.

[write the name of the composting plant, name of the product and period of validity]
Compost guarantee-parameters as in EPA-report no. 470-1999

Weeds[1]: ____ seedlings / litre
Visible impurities[2]: ____ % of dry matter

1) I.e. visible seeds and plant parts. Very low content: less than 0.5/l. Noticeable content: 0.5-2/l. Large content: more than 2/l.
2) I.e. content of plastic+metal+glass larger than 2 mm. Content should be max. 0.5 % of dry matter. Sub-results must be stated:
Plastic: ____% of dry matter Metal: ____% of dry matter Glass: ____% of dry matter

Degree of Stability	Not-ready ☐	Fresh ☐	Stable ☐	Very-stable ☐

The degree of Stability is calculated as a minimum upon the basis of Oxygen demand and Solvita test (results must be stated):
Total oxygen demand in 4 days: __ mg O_2/g dry organic matter   Solvita compost test: ___ (colour no. on chart)
Selfheating (T_{max}): __ °C   Organic-C/organic-N in water extract ___ (no unit)

Age of the compost at the time of sampling: at least ___ months.

Heavy metals (non-statutory declarable information for 100% yard waste compost)
The compost trade organisation recommends for 100% yard waste compost determination of Cd and Pb.
Observes present limit values: yes: ☐ no: ☐

Content as mg/kg dry matter		Average	Limit value
Cadmium	(Cd)	____	0,8
Lead	(Pb)	____	120 (60[2])
Mercury	(Hg)	____	0,8
Nickel	(Ni)	____	30
Arsenic[1]	(As)	____	25[1]
Chromium	(Cr)	____	100
Zinc	(Zn)	____	4000
Copper	(Cu)	____	1000

1) Applies for source separated household waste compost and sewage sludge compost. 2) Specific limit value if used in private gardens.

Sanitary treatment (non-statutory declarable information for 100% yard waste compost)
Stabilised/composted: ☐ Controlled composting: ☐ controlled deactivation/sanitation: ☐
according to Annex 3 in Statutory order from the Ministry of Environment and Energy no. 823 of September 16, 1996.

Organic pollutants (non-statutory declarable information for 100% yard waste compost)
Observes present limit values: yes: ☐ no: ☐

Content as mg/kg dry matter		Average	Limit value[1]
DEHP	(e.g. softeners in pvc-plastic)	____	100
LAS	(surfactants, in detergents)	____	2600
NPE	(surfactants, emulsifiers)	____	50
PAH	(e.g. from inadequate combustion)	____	6

1) Applies for source separated household waste compost and sewage sludge compost.

Sample taking and quality control
Samples are taken according to the directions from The Plant Directorate. The procedure for the internal quality control and the analyse reports from the external laboratory can be forwarded.