Home-made composts' quality

A review

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Table of contents

Introduction

The constant increase in waste volume and the consideration of environmental issues to its management has led European countries to adopt various regulatory measures in order to minimize waste and to enforce good management. Directive 2006/12/EC specified that member states shall take appropriate measures to encourage recycling of organic substances, including composting and other biological transformation processes (Parlement européen and Conseil, 2006).

Among solutions to manage organic wastes, home composting represents an interesting way to divert them from landfill but also from a collective management. Nevertheless, home composting systems have not yet been largely demonstrated as economically, sanitary and environmentally advantageous. Indeed, the amount of waste really diverted from collection by this way as to be verified. Moreover, voluntary households will commit themselves to compost their waste and will continue in this way only if they can be sure that composting is safe for them and that they can obtain a valuable product. However unlike industrial facilities, households can't easily order quality analysis of their composts. As a consequence simpler ways to assess home-made compost's quality have to be proposed and validated.

Thus, the objective of this document is to review which criteria can assess compost quality, which are the existing standards and which thresholds they specify. Moreover this document summarizes available data on home-made compost's quality and gathers information about other indicators that could be used for domestic composts quality assessment.

Which physico-chemical criteria for assessing compost quality?

Composting is a way to divert organic waste but the main interest of this biological treatment is to recycle organic matter in a valuable product that can return to soil. In this objective, compost quality must concern three main aspects:

- organic amendment properties: addition of organic amendments has been proven useful to restore the quality of degraded soil that can limit agricultural productivity (Evanylo *et al.*, 2008). A soil amendment is a material added to soil that will improve its physical properties, such as water retention, permeability, water infiltration, aeration or structure. The goal is to provide a better environment for roots and thus enhance the plant development.

- Fertilizing effect: fertilizers are applied on soil to promote plant nutrition thanks to the provision of macronutrients (nitrogen, phosphorus and potassium) and other micronutrients. The major goal of fertilizer is thus to improve soil fertility and production yield of crop cultivation.

- Innocuousness: the safe use of organic wastes on land depends on several factors including its potential impacts on general environment (soils, water resources, air…) and possible impacts on animal and human health (infections for compost handlers and users, odour issues…). Using organic residues on agricultural land can bring environmental impacts such as groundwater pollution or harmful gaseous emissions. These later issues will not be properly discussed in this paper. They can be related to parameters presented here but they are predominantly influenced by the dose used on land and the period of application.

Indicators for organic amendment properties

A soil amendment is defined as a material added to soil whose principal aim is to maintain or improve soil physical properties or activity.

The main considered characteristics for amendment properties are the following:

- Dry matter content: important characteristic for the practical storage and use of the amendment.

- Organic matter content: It defines the amount of organic matter added to the soil to reinforce its structure and its potential as growing medium.

- Carbon and nitrogen content: carbon and nitrogen are the most important constituents of the organic matter. Depending on the balance between the organic and mineral forms of these elements, carbon and nitrogen will lead either to the improvement of the soil biological properties, either to the soil nutritive properties.

- Van Soest biochemical fractionation (Van Soest and Wine, 1967) (soluble organic fraction, hemicellulosic-like fraction, cellulosic-like fraction and ligno-cellulosic-like fraction): Organic amendment properties are defined by the structural nature of the organic matter added to soil. Biochemical fractionation of the organic matter quantifies categories of soluble compounds that are extracted in the same conditions. The extracted fractions have a decreasing biodegradability and growing structural properties for soils. That is why these amount of these different fractions have been used to define stability indices in France (IBS – index of biological stability, or Tr – proportion of residual organic matter)(AFNOR, 2005)

- Humic substances content: humic substances are the more stable component of the organic matter and are essential to improve soil structure, fertility and health.(Campitelli and Ceppi, 2008). Indeed, humic acids can contribute to the soil buffer capacity and soil cation exchange capacity. Moreover, humic acids affects heavy metal solubility and mobility in soil (Diacono and Montemurro, 2010)

- Cation exchange capacity (CEC): CEC addresses soil quality characterization as growing medium. Indeed it determines the substrate ability to absorb cations as those known as nutrients for plants (Ca, Mg, K, Na). As a consequence, increase of soil CEC is interesting for longer soil fertility. Evolution of CEC is also a good indicator of organic matter humification process. Moreover, high CEC can also contribute to improve contaminants retention avoiding leaching to groundwater (Novoa-Munoz *et al.*, 2008)

Indicators for fertilizing effect

The fertilization potential of an organic product is estimated by its total content of nutrients and by the availability of these nutrients for plants.

- Nitrogen content: Total nitrogen, nitrates (NO_3^-) and ammonium (NH_4^+) contents are important characteristics as they are indicative of nitrogen availability for plants growth.
- Potassium (K) and Phosphorus (P): P and K are the two others main nutrients for plant fertilization. Soluble forms of these components can be easily assimilated by plants.
- Other mineral contents like manganese (Mg), calcium (Ca) and sodium (Na) can also be considered.

Indicators for Innocuousness assessment

Innocuousness of organic products includes prevention of impacts on potential users, prevention of environmental problems (fauna, air, water and soil) and lastly prevention of phyto-toxicity for plants.

- Inorganic impurities: content of the compost in terms of inert material such as plastics, particles of glass or stones
- Heavy metals: heavy metals (as Cadmium, Cobalt, Chromium, Copper, Mercury, Nickel, Lead, Zinc): these substances are not concerned by biodegradation and may induce metal accumulation in soil. These potentially toxic elements may then be absorbed by plants, animal or micro-organisms.
- Ammonium content is important as fertilizing property of an organic product. But when too much concentrated ammonium may also lead to phytotoxic effects for plants.
- Organic contaminants: Here are considered organic molecules of two types (Polycyclic aromatic hydrocarbons and biphenyl polychlorinated compounds). These are pollutants persistent in the environment (Hargreaves *et al.*, 2008).
- Organic matter stability: Biological stability is an important characteristic for organic amendments and fertilizers as it avoids management issues such as further fermentation leading to odorous emissions and limits further decomposition in soil. Stability can be assessed by biological parameters such as respirometric methods (oxygen consumption or carbon dioxide production) (Ponsa *et al.*, 2008), self heating potential (Brinton *et al.*, 1995), or by chemical parameters as C/N ratio (Mathur *et al.*, 1993).
- pH, salinity and conductivity: pH is important for innocuousness as it controls the behaviour of metals in soils (Kapanen and Itavaara, 2001). pH is also an indicator of the presence of organic acids that can be phyto-toxic for plant growth. Salinity has to be controlled because

excess salt concentration has negative effects on plants germination and soil biological activity (Hargreaves *et al.*, 2008). Finally conductivity is a way to measure salt concentration.

- Phyto-toxicity: It concerns characteristics affecting plant germination or root growth. To measure immediate phyto-toxicity, tests of seed germination inhibition are used (measurement of germination percentage en root length).

- Pathogens: Potential impacts on human health of an organic product can be assessed through the quantification of coliform bacteria. Escherichia Coli is reported to be the most representative faecal coliforms (Hassen *et al.*, 2001), but faecal streptococci are commonly considered as the best indicators of faecal pollution. Among pathogens, Salmonella are the most studied for indicating pathogens behaviour insludge and composts (Moletta, 2009). Helminth eggs are also currently quantified as they present high resistance to environmental factors.

Existing standards concerning compost's quality

Different European standards exist on organic amendment properties. All consider different types of composts but none takes into account home composting.

Considering industrial soil amendments and growing media, an EC report (AFNOR, 2001) proposes a list of products that can be labelled in this way and the specification they have to comply with. But quality standards still depends on national responsibility.

Examples of parameters and thresholds considered into soil amendments and growing media quality standards or guidelines (non exhaustive list) are listed in table 1.

	Germany – Quality Label RAL-GZ 251 (For (a) fresh compost ; (b) mature compost ; (c) mulch compost ; (d) substrate compost)	**Great-Britain PAS 100:2005** (BSI, 2010) (apply to compost from source separated biowaste)	**Switzerland – Quality Guidelines for composts 2010** (Inspektoratkommision des Gründgutbranche, 2010) (values given for horticultural use: (a)on field, (b) covered)	**France - NF U 44-051** (AFNOR, 2006) (Apply to soil improvers excluding those coming from wastewater treatment sludge)	**Canada - CCME Compost Quality Guidelines** (CCME, 2005) (compost that can be used in any type of application)
Dry matter (DM)	(A), (b) and (c) > 55 %	-	(a) >50 %* (b) >55%*	> 30% of total weight	-
Organic matter (OM)	(a) > 30 % DM (b) > 15 % DM (c) - (d) > 15 % DM	-	(a) < 50 % DM* (b) < 40 % DM*	> 20 or 25 % of total weight (depending on the raw substrate)	-
Decomposition degree	(a) II or III (b) IV or V (c) - (d) V	-	-	-	-
pH-value	-	-	(a) < 7.8 (b) <7.5	-	-
Salt content	(d) <2.5 or 5 g/l depending on the mixed component quantity	-	(a) < 20 gKCleq/kg DM (b) < 10 gKCleq/kg DM	-	-
Impurities	(Total glass, metal, plastic and any other non-stone fragments > 2 mm) <0.5 % DM	(Total glass, metal, plastic and any other non-stone fragments > 2 mm) <0.5 % DM of which 0.25 is plastic	Films + PSE>5mm < 0.1 % DM (Total glass, metal, plastic and any other non-stone fragments > 2 mm) < 0.5 % DM	Films + PSE>5mm < 0.3% of DM Other plastics >5 mm <0.8% of DM Glass + metals > 2mm <2 % of DM	No sharp foreign matter>3mm per 500 ml compost No more than 1 piece of foreign matter>25 mm in 500 ml
Stones (> 5 mm)	< 5 % DM	<8 or 16 % of DM (depending on the grade of the compost)	As low as possible	-	-
Arsenic (As)	-	-	-	< 18 mg/kg DM	< 13 mg/kg DM
Cobalt (Co)	-	-	-	-	< 34 mg/kg

					DM
Molybdenum (Mo)	-	-	-	-	< 5 mg/kg DM
Selenium (Se)	-	-	-	< 12 mg/kg DM	< 2 mg/kg DM
Lead (Pb)	< 150 mg/kg DM	< 200 mg/kg DM	< 120 mg/kg DM	< 180 mg/kg DM	< 150 mg/kg DM
Chromium (Cr)	< 100 mg/kg DM	< 100 mg/kg DM	-	< 120 mg/kg DM	< 210 mg/kg DM
Nickel (Ni)	< 50 mg/kg DM	< 50 mg/kg DM	< 30 mg/kg DM	< 60 mg/kg DM	< 62 mg/kg DM
Zinc (Zn)	< 400 mg/kg DM	< 400 mg/kg DM	< 400 mg/kg DM	< 600 mg/kg DM < 1200 mg/kg OM	< 700 mg/kg DM
Cadmium (cd)	< 1.5 mg/kg DM	< 1.5 mg/kg DM	< 1 mg/kg DM	< 3 mg/kg DM	< 3 mg/kg DM
Copper (Cu)	< 100 mg/kg DM	< 200 mg/kg DM	< 100 mg/kg DM	< 300 mg/kg DM < 600 mg/kg OM	< 400 mg/kg DM
Mercury (Hg)	< 1 mg/kg DM	< 1 mg/kg DM	< 1 mg/kg DM	< 2 mg/kg DM	< 0.8 mg/kg DM
Grain size	(c) particle size < 5 mm = maximum 10 % of volume (d) < 25 mm and 50 % of the volume > 5 mm	-	(a) < 25 mm (b) < 15 mm	-	-
C/N	-	-	-	> 8	-
N	-	-	(a) > 10 g/kg DM* (b) > 12 g/kg DM*	< 3 % of total weight	-
N-NH4^{+}	-	-	(a) < 200 mg N/kg DM (b) < 40 mg N/kg DM	-	-
N-NO3^{-}	-	-	(a) > 80 mg N/kg DM (b) > 160 mg N/ kg DM	-	-
N-NO2^{-}	-	-	(a) < 20 mg N / kg DM* (b) < 10 mg N / kg DM*	-	-
N-NO2^{-} + N-NO3^{-} + N-NH4^{+} + N-urea	-	-	-	< 33 % of total N	-
N-NO3^{-} + N-NH4^{+}	(d) <300 or 600 mg/l depending on the mixed component quantity				-
N-NO$_3^-$/(N-NH$_4^+$+ N-NO$_3^-$)	-	-	(a) > 0.4 (b) > 0.8		-
P_2O_5	(d) <1200 or 2400 mg/l depending on the mixed component quantity	-	-	< 3 % of total weight	-
K_2O	(d) <2000 or 4000 mg/l depending on the mixed component quantity	-	-	< 3 % of total weight	-

$N + P_2O_5 + K_2O$	-	-	-	< 7% of total weight	-
Cl^-	(d) <500 or 1000 mg/l depending on the mixed component quantity	-	-	-	-
Na^+	(d) <250 or 500 mg/l depending on the mixed component quantity	-	-	-	-
$CaCO_3$	<10 % DM	-	-	-	-
Germinable seeds	As low as possible	0	-	-	-
Salmonella	0	0 in 25g fresh mass	-	0 in 1 g of compost (or in 25 g of compost for market gardening)	0
Escherichia Coli	-	< 1000 CFU / g fresh mass	-	-	-
Fecal coliforms	-	-	-	-	< 1000 MPN/g DM
Viable helminth eggs	-	-	-	Absence in 1.5 g of compost	-
Microbial respiration rate	-	< 16 mg CO_2 / g OM / day	-	-	< 400 mg O_2/kg OM/h or < 4 mg CO_2/kg OM/ day
Germination test **Cress seeds (open)** **Cress seeds (closed)** **Lettuce** **Beans** **Raygrass** **Reduction in germination of plants in amended compost** **Reduction in plant mass above surface in amended compost** **Description of any visible abnormalities**	-	< 20 % of germinated plant in peat control <20 % of plant mass above surface in peat control No abnormalities	(a) > 50 % of the reference (b) > 75 % of the reference (a) > 25 % of the reference (b) > 50 % of the reference (a) > 50 % of the reference* (b) > 70 % of the reference (b) > 70 % of the reference* (b) > 70 % of the reference*	-	-
Polycyclic aromatic hydrocarbons **Fluoranthene** **Benzo(b)fluoranthene** **Benzo(a)pyrene**		-	<4 mg/kg DM	<4 mg/kg DM <2.5 mg/kgDM <1.5 mg/kgDM	-
Polychlorinated		-	20. 10^{-12} eq toxicity / kg DM	-	-

biphenyls, dioxine, Furane					

* Recommended value but not mandatory

Table 1 – Example of quality standards or guidelines for composts

As it can be seen in table 1, all quality standards or guidelines considered parameters for innocuousness assessment. But the thresholds differ from one country to another.

Parameters assessing amendment properties or fertilizing effects are not largely considered. Only guidelines that described different types of composts linked with different uses give detailed thresholds for nutrient contents, salinity, etc.

General knowledge on home-made compost's quality

Because of the lack of guidelines and standards concerning home-composting quality and also because of the expenses that represents composts analysis, data about home-made composts are very scarce.

Few articles presented home-composting studies in the literature review. Indeed only four scientific papers really dealing with home-made compost quality have been found:

- (Preston *et al.*, 1998): a Canadian study with the objective of characterising backyard composts samples from three provinces with different composting techniques (wood bin, plastic bin, pile, with or without mixing, etc.). Among samples, physical aspect of the compost varied but the general tendency was a brown fine and friable product.
- (Jasim and Smith, 2003): a study performed in Great Britain about the practibility of Home composting for the management of biodegradable sold waste. Quality of 64 home-made composts, all obtained in plastic bins, was investigated.
- (Alexander, 2009): this study aimed at assessing backyard compost quality as potting medium.
- (Ryckeboer *et al.*, 2002): these scientists studied the fate of plant pathogens and seeds during backyard composting.

Moreover even if some associations and local collectivities have performed compost sampling and analysis to assess their home-composting programs, results are rarely publicized.

Most relevant data that have been found are shown in table 2.

	Preston et al., 1998 (8 samples)	Jasim and Smith, 2003	Survey ADEME/Conseil régional de Picardie, 2001 (3 samples)	Survey ACR+, 2009			
				Heap	Plastic bin	Wood box	Worm composting
Dry matter (%)	-	17.2-75.4	30.4-67.5	49.2	35.8	48.2	21.4
Organic matter (% DM)	17.6 – 51.8	6.6-69.3	21.3-64.6	25.8	44.8	30.9	58.3
pH	6.15-6.93	5.6-9.3	7.5-8.9	7.7	.2	7.4	8.0
Conductivity (µS.cm-1)	-	462-1618	-	732	2065	1089	1541
Total carbon (%DM)	9.5-30.7	-	10.7-32.3	-	-	-	-
Total Nitrogen (%DM)	0.55-1.76	1.1-6.1	0.43-2.03	-	-	-	-
C/N	11.9-22.2		11.4-24.6	-	-	-	-
$N\text{-}NH_4^+$ (mg/kg DM)	16-43	0.9-37.7	30-200	-	-	-	-
$N\text{-}NO_3^-$ (mg/kg DM)	46-333	8.8-96.9	-	-	-	-	-
$N\text{-}NO_2^-$ (mg/kg DM)	-	0.1-3.4	-	-	-	-	-
P total (%DM)	0.16-53	0.1-3.4	0.12-0.87	0.19	0.27	0.29	-
P extractible (%DM)	0.01-0.11	0.02-0.2	-	-	-	-	-
K total (% DM)	-	0.42-4.15	0.44-1.28	0.33	0.87	0.36	-
CEC (cmol+/kg DM)	34.2-68.3	-	-	-	-	-	-
As (mg/kg)	23-52	-	-	-	-	-	-
Cd (mg/kg)	1.7-3.2	-	-	0.5	0.8	0.7	-
Co (mg/kg)	2-9	-	-	-	-	-	-
Cr (mg/kg)	44-109	-	-	14.9	45.4	20.2	-
Cu (mg/kg)	43-98	-	-	23	54	32	-
Mn (mg/kg)	429-889	-	-	-	-	-	-
Ni (mg/kg)	17-33	-	-	12	10.4	10.2	-
Pb (mg/kg)	40-280	-	-	48	35	41	-
Zn (mg/kg)	111-394	-	-	178	175	185	-

Table 2 – Example of quality analysis for home-made composts

We did not find numerous data for home-made compost quality but we can see that analytical values are in the same range. Moreover these values are generally in good agreement with the standards and guidelines given for industrial composts.

How assessing home-made compost's quality without chemical indicators?

As shown previously, compost quality can be largely characterized considering physico-chemical analysis. Inconvenience of these parameters is that they require sample analysis in a specialized laboratory and that these analyses are expensive. Thus these physico-chemical criteria can not be easily used by home-compost makers or masters-composters to assess home-made compost's quality. As a consequence more sensory parameters are often used by users to assess their compost quality and how they can use it.

Guidebooks given to home-composters propose some parameters to assess the end of the composting process and the quality of the compost (Jobard, 2008). Most frequently cited parameters are:

- Temperature

The biological activity developed during the composting treatment also produces heat. Thermal balance between this heat production and heat losses through the ambient air induces temperature variation in the composting mass (Tremier *et al.*, 2007). Composting guidebooks generally indicates that ideal temperature for composting ranges from 40℃ and 70℃. Nevertheless, these temperatures are more representative of large scale composting systems. Furthermore, temperature is linked to the stage of the process and not directly to the quality of the compost. Thus temperature is an interesting indicator of the composting behaviour but can not be interpreted in terms of compost agronomic quality and innocuousness.

- Moisture

Moisture is also important to state on a potential and practical use of the amendment. Actually important moisture can bring particular issues such as odours and difficulties to store and distribute the amendment (Teglia *et al.*, 2010). Moisture can be measured by drying a compost sample but it can also be assessed thanks to a simple manual test: the fist test.

- Odours

Along composting bad odours may occur. They are due to organic molecules such as fatty acids, aldehydes and ketone and also to nitrogenous and sulphurous components. These bad odours can be linked to the raw waste added in the compost. These odours decrease during composting and tend to disappear. Other bad odours may occur along composting particularly when aeration is badly managed. The final compost is generally characterized by a humus-like odour, due to geosmine, a molecule that is produced along the curing phase of composting (Tremier *et al.*, 2007). Thus odour can be used both as an indicator of the composting behaviour and as an indicator of the compost maturity stage.

Measuring odour is not a simple problem because the way to sample emissions is not standardized (Bockreis and Steinberg, 2005). Moreover analysis of the samples can be complex and expensive. In order to simplify odour characterization, odour wheels have been proposed. Odour wheels are a simple method of classification of the odour character (i.e. quality, note, type, group or category) and intensity of each characteristic (Suffet and Rosenfeld, 2007). A specific odour wheel has been established for composting and used to assess odours on industrial composting plants (Rosenfeld *et al.*, 2007)

- Presence of living organisms

Presence of living organisms such as worms in the home-made compost is generally the sign of good environmental conditions (pH, salinity, temperature, moisture, etc.) for biological activity and as a consequence it is interpreted as the proof of a good management of the composting process.

- Colour of the compost

On a colour point of view, humic substances, synthesized during the curing period of the composting process, are aromatic molecules with numerous double bonds, which are responsible for black colour of stabilized composts. Colour is often visually estimated and compost should be dark brown or black (Epstein, 1997). It does not exist a colour wheel for compost maturity.

- Texture

In order to be easily usable, guidebooks for home composting specify that good compost should have a fine and crumbly texture.

- Homogeneity

Homogeneous colour and texture characterize a well managed composting treatment. Indeed it is the sign of frequent turning and homogenous conditions for biological activity.

As already noted, there is a good agreement among home-composting experts about the interest of these sensory indicators to assess the quality of home-made compost. Nevertheless it does not exist any correlation between physico-chemical characteristics assessing innocuousness and agronomic properties of composts and these sensory parameters.

Conclusion

Because of their large scale application to soil, a large amount of work has been performed concerning the quality of industrial composts. Standards and guidelines have been proposed to verify their innocuousness for humans, animals, plants and soils and also to asses their agronomic interest.

As home-made composts were not intended to be sold and spread at large scale, no standard or guideline was proposed for them until nowadays. However large promotion of home-composting leads to more and more production of home-made compost. Thus assessment of the quality of home-made composts becomes of crucial interest: (1) to assure public health and environmental safety; (2) to encourage home-composters and to give them guidelines for composting management and compost use.

Parameters used for industrial compost characterization can be used to state on the quality of home-made compost. Sampling campaigns could be organised by local or regional municipalities to assess environmental impacts of home composting but it could be very expensive. Moreover, this physico-chemical characterization can not be easily performed by individual composters who want to judge of their way to manage composting and of the quality of their composts. In these latter objectives, sensory parameters are much easier to use.

If relations could be found between physico-chemical parameters and sensory parameters, then it would be possible for individual composters to state on the quality of their composts and to inform local institutions of this quality, reducing by the way the need of large sampling and analitycal campaigns.

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