# Your Manure – a 'fresh' look at Compost

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Optimal Soil Management is the required condition for sustainable successful organic production. Besides crop residues and green manures, animal manures and compost play a manor role in successful organic farming. The question is how much animal manure and how much compost should be used in order to make the farm more sustainable? There is no specific rule. Sometimes it is better to use manure and sometimes it is better to use compost. That decision depends on the specific situation, and the long range sustainable farm planning.

**Effective Organic Matter and Humification Coëfficients**

First of all, we need to look at the quantity of organic matter present in the soil, and how we can increase this quantity of organic matter.

Especially we need to look at the quantity of EFFICTIVE ORGANIC MATTER that is present in the soil. EFFECTIVE ORGANIC MATTER or E.O.M. is that part of organic matter which is, one year after application, not yet decomposed, thus contributing to soil organic matter build up in the long term. When fresh organic material, such as crop residue, green manure, animal manure or compost is incorporated into the soil part of it is broken down immediately through mineralization.

Roughly half of the soil organic matter is soluble, which means that it is broken down mineralized after it is incorporated. The other half, which is not soluble, will be broken down over time through humification. Humification is the breakdown of lignocellulosic organic matter. This breakdown takes place through enzymatic action. Humification occurs very slowly over time.

Effective Organic Matter is present in all crops, green manures, livestock manures and composts, but they all have a different humification coëfficient. The humification coëfficient will tell us how much effective organic matter is produced.

| | | |
|---|---|---|
| The humification coëfficient for | solid cow manure is | 50% |
| | Broiler manure | 50% |
| | Liquid cow manure | 15% |
| | Liquid sow manure | 12% |
| | Crop residues | 30% |
| | Green manures | 30% |
| | Compost (general) | 75% |
| | VFG-compost | 86% |
| | Champost | 91% |
| | Greencompost | 95% |

VFG-compost (sometimes called biocompost is actually composted source separated organic municipal waste)

Champost is composted mushroom waste (medium and mushrooms)

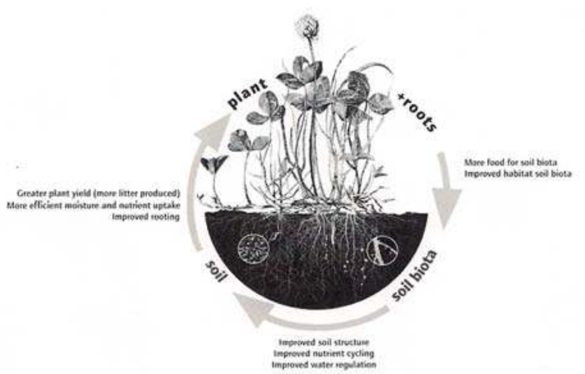
Greencompost is composted organic landscape waste (branches, twigs, Christmas trees, shrubs, discarded sod etc.).

The table above shows that composts have a very high humification coefficient.  For general compost, for example, 75% of its organic matter is effective organic matter.  Compost will build up soil organic much quicker than any other type of manure.

**Biota Flywheel**

The effective organic matter forms the clay-humus complex, which is responsible for cation-nutrient exchange.  This how crops feed themselves.

Effective organic matter in the soil contains 58% effective organic carbon.  This carbon is the energy (fuel) that drives the soil biota (organisms), nutrient exchange between the roots and the soil, and finally the growth of the crops.  This cycle is referred to by scientists as the biota flywheel.  (see picture below)




Biota flywheel

Soil organic matter breaks down each year.  On average this break down is roughly 2% or 1600 to 2000 kg per hectare (2.5 acres) per year.  This 1600- 2000 kg must be replaced each year, preferably more in order to build up the soil organic matter.  The incorporation of effective organic matter will just do that, more so than an application of solid or liquid manure.

Here is an example:

| Manures and composts | E.O.M. kg/tonne |
|---|---|
| Solid cow manure | 75 |
| Liquid cow manure | 20 |
| VFG-compost | 143 |
| Greencompost | 233 |
| Champost | 110 |

To replace 2000 kg of lost organic matter, we need to apply 27 tonnes of solid manure, 100 tonnes of liquid manure, 14 tonnes of VFG-compost, 9 tonnes of greencompost or 18 tonnes of champost.

This shows the importance of yearly application of composts to maintain soil organic matter at adequate levels.

Therefore it is important to make good quality compost.   This requires a compost management system.  Here are some guidelines.

## Composting

On-farm composting consists of two processes: active aerobic composting and curing. During the active aerobic composting process microorganisms consume oxygen ($O_2$) while feeding on the organic material in manure. While feeding the organisms produce heat, $CO_2$ and water vapour. During this stage most of the easily composable organic matter is decomposed. What is left over is the 75% effective organic matter.

A management plan is needed to maintain proper composting conditions, because several factors influence the composting process.

Factors affecting the composting process and acceptable ranges

| Factor | Acceptable range |
|---|---|
| Temperature | 54 – 60 $^0$C |
| Carbon-to-Nitrogen Ratio (C:N) | 25:1 – 30:1 |
| Aeration, percent Oxygen | > 5% |
| Moisture content | 50 – 60% |
| Porosity | 30 – 36 |
| pH | 6.5 – 7.5 |

If the proper conditions are met, composting should start immediately. The most important conditions to be monitored are temperature, which should be maintained at 54 – 66 $^0$C, and the moisture content at 50 – 60%. With the right moisture content the composting material should rapidly increase to 40 $^0$C (Mesophilic phase) within a day or two, and to 50 – 60 $^0$C (Thermophilic Phase) within a week.

Monitoring the temperature is essential for the composting process to proceed. The temperature is checked with a compost thermometer, which has a 1 meter prope.
The temperature is kept between 55 and 65 $^0$C for 14 days, to kill any pathogenic bacteria and weed seeds. Turn the compost after 3 days, 8 days, 22 days, 29 days, and 39 days to maintain the temperature. Turn the compost when the temperature begins to drop.

## Quality of the Feedstock

The raw organic material used for composting is called feedstock. The quality of the feedstock determines the duration of the composting process and the quality of the end product.

## Carbon-to-Nitrogen Ratio

To start off the composting process the feedstock needs to be in the correct conditions, meaning that the feedstock has to have a carbon-to-nitrogen ratio (C/N) of (20:1 to 30:1), and a moisture content of (50 – 60)%. The carbon-to-nitrogen ratio of manure is a very important factor that affects the whole composting process because microbes need 20 to 25 times more carbon than nitrogen to remain active. The ratio should be between 25:1 and 30:1 at the beginning. The microorganisms **digest carbon as an energy source** and **ingest nitrogen for protein and reproduction**.

**NOTE:** ***Here the carbon stays on the farm. In digesting off-farm the carbon is removed from the farm to feed bacteria off-farm. The return of the energy to the farm is 50-80% less.***
Softwood shavings (C/N 250:1), sawdust (C/N 500:1) and straw (C/N 80:1) are a good source of carbon. Other inexpensive sources of carbon include shredded paper (C/N 170:1) or cardboard (C/N 400:1). It is important to have the proper C:N ratios when mixing various materials. Materials can be blended together to attain the proper ratio of 25:1 to 30:1. The necessary formulas and sample calculations are in the booklet, "***Your Manure – a fresh look at compost***". This booklet (30 pages) can be purchased for $25.00 from the presenter (Email: william.langenberg@sympatico.ca).

## Quality Assurance Parameters for Composts

### Dry Matter (DM)

The Dry Matter (DM) of each identified product should be at least 55%, preferably in the 6-0 – 70% range.

### Organic Matter (OM)

The Organic Matter content on the analysis can be reported under two different numbers, OM (fresh), or OM (dry). The minimum number varies from country to country (varying between 10 and 20%.

### Effective Organic Matter (EOM)

The Effective Organic Matter (EOM) is not a quality parameter. EOM is closely tied to Organic Matter. When applying composts to agricultural land, a high EOM value will help in reducing the application of the nutrients, Nitrogen and Phospate.

### Salinity (Electrical Conductivity)

The salinity or EC value should not exceed 5,500 µS/cm. In North America, various units are used to measure EC values.

### Bulk density

Although the bulk density is not a quality characteristic, it is an important marketing tool when determining the market price, either in bulk or retail. The EU considers a bulk density of less than 600 kg / $m^3$ marketable. Reporting the bulk density becomes important when the product is marketed as a growing medium to the horticultural sector.

## Heavy Metals in 'Organic' Compost

"What is organic compost?"
In 1991, the European Union established a separate set of acceptable limits of heavy metals for "organic" compost called, the "EEC's Organic Rule" #20992/91, Brussels, 1991. The limits for heavy metals under these organic rules are listed in the table below. The Dutch Independent Inspection Organization, 'SKAL', recognized by 'IFOAM (International Federation of Organic Agricultural Movement', set the Dutch organic heavy metals limits, under the SKAL norms. The SKAL NORMS, along with the EU organic norms and the limits set by the Ontario Ministry of Environment are listed in this table of Analysis and Standards for compost table.

## Analysis and Standards for GREENCOMPOST

| PHYSICAL | SAMPLE | UNIT | | NORMS | |
|---|---|---|---|---|---|
| Dry Matter (DM) | 556 | kg / tonne | Fresh Wt | > 550 | Fresh Wt |
| Moisture | 444 | kg / tonne | | | |
| Organic Matter | 301 | kg / tonne | Fresh Wt | > 100 | Fresh Wt |
| Effective Organic Matter | 160 | kg / tonne | Fresh Wt | | |
| Electrical conductivity | 765 | µS/cm | | < 5500 | |
| Chlorides | 600 | mg / l | | | |
| N-TOTAL | 9.3 | kg / tonne | | | |
| N-TOTAL | 18.4 | gm / kg DM | | | |
| N-NH4 | 43 | mg / l | | | |
| N-NO3 | 25 | mg / l | | | |
| N-NO3 / N-NH4 | 0.58 | | | | |
| N-organic | | | | | |
| C/N | 17.3 | | | | |
| P2O5 | 3.4 | kg / tonne | | | |
| K2O | 6.2 | kg / tonne | | | |
| CaO | 17 | kg / tonne | | | |
| MgO | 3.2 | kg / tonne | | | |

| | | | | Maximum Allowable Concentrations of Heavy Metals, expressed in mg / kg Dry Weight | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **HEAVY METALS** | **Dry Wt** | | | **ONTARIO** | **EU-ORGANIC** | **SKAL** | **DUTCH (Very clean)** | **DUTCH (Standard)** | **EU (Proposed)** | **STANDARD** |
| **Cadmium (Cd)** | 0.62 | mg / kg | **Cd** | 3 | 0.7 | 0.7 | 0.7 | 1 | 1.3 | Cd |
| **Chromium (Cr)** | 16.5 | mg / kg | **Cr** | 210 | 70 | 70 | 50 | 50 | 60 | Cr |
| **Copper (Cu)** | 24.4 | mg / kg | **Cu** | 100 | 70 | 70 | 25 | 90 | 110 | Hg |
| **Mercury (Hg)** | 0.1 | mg / kg | **Hg** | 0.8 | 0.4 | 0.4 | 0.2 | 0.3 | 0.45 | Ni |
| **Nickel (Ni)** | 9.5 | mg / kg | **Ni** | 62 | 25 | 25 | 10 | 20 | 40 | Pb |
| **Lead (Pb)** | 31.5 | mg / kg | **Pb** | 150 | 45 | 45 | 75 | 100 | 130 | Zn |
| **Zinc (Zn)** | 137 | mg / kg | **Zn** | 500 | 200 | 200 | 75 | 290 | 400 | As |
| **Arsenic (As)** | 2.78 | mg / kg | **As** | 13 | --- | --- | 5 | 15 | --- | |

| **OTHERS** | | | | **MAXIMUM ALLOWABLE LEVELS** |
|---|---|---|---|---|
| **Contaminants < 2 mm** | 0.1 | kg / tonne | Fresh Wt | < 5.0 kg / tonne |
| **Stones > 5 mm** | 3.5 | kg / tonne | Fresh Wt | < 20.0 kg / tonne |
| **Viable seeds** | 0 | / litre | | 0 / litre |
| **Phytotoxicity** | 4.2 | % | | < 10 % |
| **Maturity** | V | | | IV or V |
| **Maturity (Temp.)** | 23.5 | Celcius | | Not reheat greater than 20C above ambient temperature |

**AFFINAGE**

**Screen size;**

Particle Size < 25 mm
0 - 5 mm - top dressing, hydro seeding
0 - 10 mm - growing media, home gardens
0 - 15 mm - soil improver, bedding compost barns
0 - 25 mm - soil mulch, soil improver - agriculture

# Anaerobic composting, better known as digesting

In anaerobic composting oxygen is removed and the material is put under pressure in a digester. In anaerobic composting of manure a co-substrate (high in energy) is needed to digest the manure. The co-substrate can be a primary energy crop, such as corn, barley or wheat. The digested left-over of the original organic material is called digestate. The digestate is used an organic fertilizer on farm fields.

## There are three groups of co-substrates

**Primary energy crops**
Anaerobic digesting of primary energy crops, such as annual field crops (corn, barley, wheat, canola and hemp) produces ethanol. Digesting perennial crops (miscanthus, switch grass and canary grass produces biobuthanol.

**Primary bi-products**
Anaerobic digesting of primary bioproducts (woody greenwaste, landscape and horticultural waste also produces buthanol

**Secondary bi-products**
Secondary bi-products are wastes from the food-chain (municipal organic waste and grocery store wastes).

Secondary bi-products produce the highest quantity of biogas compared to primary energy crops and manures.

**The question is: "How sustainable is digesting organic waste and what is the quality of digestate?**

Example of ingredients of a digestate, average of 23-digesters in Denmark

Input 75% liquid manure and 25% VFG-waste (biowaste)

| pH | DM | $N_{TOT}$ | $NH_4^+$ | P | K |
|---|---|---|---|---|---|
| 7.6 | 5% | 4.6 kg /t | 3.3 kg /t | 1 kg/t | 2.8 k/t |
| | 5% | 0.46% | 0.33% | 0.10% | 0.28% |

The DM content is very low because of a large input of liquid manure. More importantly, the DM content through digesting drops by 50%. The Digestate has a DM content of 6-20% of the original DM. During digesting the OM content also drops by 50 – 80%, because 50-80% of the original OM is digested into biogas. Therefore, the digestate may have an OM content of only 2-16%, **based on fresh product**.

There is no N in nitrate form, because it is an anaerobic process. Most of the organic nitrogen is changed though digestion into the readily available $NH_4^+$ cation. Since the nitrogen is not organically bound in anaerobic digestate, farmers in Europe have to declare digestate as a manure rather than a compost. Digestate is very close to a mineral $NH_3$ fertilizer.

## How sustainable are biomass-substrates that are coming directly from agriculture?

The European bioenergy sector is currently debating sustainability issues regarding the use of first generation biomass for biofuel production. The Dutch technical Commission on Soil Protection commissioned a research study into the positive and negative effects of using first generation biomass on the quality of soil. This research study was conducted by the Dutch Nutrient Management Institute (NMI). The production of bioenergy offers opportunities for maintaining good soil quality (closed C-cycle), if it is obtained from biomass from crop grown for second generation biofuels. In Canada, ethanol (a first generation biofuel) is obtained from sugers of corn kernels through bacterial action. Crops grown for second generation biofuels are NON-FOOD BIOMASS, perennial grasses, Miscanthus-gigantheus, Carnarygrass, Elephant grass, polar, willow, as long as the remaining organic matter is plowed down to compensate for the breakdown of OM. Second generation biofuels are expensive to produce. Second generation are obtained through anaerobic enzymatic action. This type of production drives up the price of fuel. There are also a number of threats. In Europe digestate must be registered as an organic fertilizer, such as animal manure, and therefore counts in the nutrient management plan. It cannot be registered as a soil improver. This could lead to insufficient application of OM and therefore may result in impoverishment of soils. At the same type there is a real risk of rising nutrient surpluses, which could lead to serious eurtrophication of soils.

$NH_4^+$-N has a positive charge, it is a cation. The nitrogen in digestate is a slow working N, because it can only be taken up by the crops through cation-exchange.

Nitrate ($NO_3^-$- N) on the other hand is an anion, which can be taken up immediately.

Here is an analyses:

**Average composition compost and digestate**

| Parameter (g/kg) | Greencompost Average | VFG-compost Average | Bio-digestate Liquid fraction | Bio-digestate Solid fraction |
|---|---|---|---|---|
| DM % | 60 | 70 | 7.5 | 24.7 |
| OM on DM | 31 | 35 | 49.5 | 75.9 |
| $N_{-TOT}$ | 8.6 | 13.4 | 5.3 | 7.2 |
| $N\text{-}_{NH4}$ | 0.9 | 0.8 | 3.5 | 3.2 |
| $N\text{-}_{ORG}$ | 6.1 | 7.7 | 1.8 | 4.0 |
| $P_2O_5$ | 7.7 | 6.3 | 3.2 | 7.7 |
| $K_20$ | 7 | 11.9 | 4.7 | 4.7 |
| MgO | 3.2 | 4.8 | 0.6 | 1.8 |
| pH | 7.6 | 7.4 | 7.6 | 8.5 |

The big question is, which one is the most sustainable with respect to soil quality. Compost or Digestate? Digesting, for example, greenwaste for the production of energy and returning the digestate to the land, results in a lot of loss of OM.
Composting greenwaste, on the other hand will maintain the OM and will result in only a small loss of $CO_2$ and $CH_4$, provided the composting is done properly.

# Digestate as box stall compost has a future

The Dutch composting company ‘Orgaworld’, in partnership with a compost dealer and a couple of dairy farmers in the Netherlands, started in 2008 an experiment to develop a boxstall bedding from composted digestate. The digestate/compost is made from digested municipal organic solid waste (VFG-waste). The digestate is dried under vacuum at a temperature range of 72 – 74 $^{0}$C for about three days. After 3 days, the compost is cooled, cleaned from stones and twigs and then inoculated with ‘positive’ bacteria and filtered (sieved) to a maximum particle size of about 10 mm. The exposure to high temperature during the three days of heating and drying kills off most of the bad bacteria, such as Klebsiella, salmonella and coliform bacteria.

You have to get used to the dark grey coloured bedding. The dairy farmers, who used the compost, reported that the cows lie down easier and have less udder, claw and hock problems. Udder and claw problems completely disappeared. Some of the farmers claim that there are fewer flies in the barn because of the compost. Another farmer said: “My cows have hair again on their hocks.”
The compost forms a dens and solid bedding that completely covers the cement stall floor. The urine will collect in puddles on top of the compost and can be easily scraped off. If you have a grate in the floor and the compost falls through, it will completely dissolve in the liquid manure tank. There is no sedimentation forming in a liquid tank. The compost has a pH of 7.2, so there is no problem with acidifying the soil.

The cost of using compost as bedding is about $35.00 per boxstall, compared to $140.00 using sawdust. This is a 75% reduction.

Composition bedding-compost

| **Constituent** | **kg / m$^3$** | **lbs / cu.yd.** | **%** |
|---|---|---|---|
| DM | 667 | 1129 | 66.7 |
| OM | 205 | 347 | 20.5 |
| **Nutrients** | **kg / kg m$^3$** | **Lbs / cu. yd** | **%** |
| Nitrogen (N) | 5.2 | 8.8 | 0.78 |
| Phosphate (P) | 4.8 | 8.1 | 0.72 |
| Potassium (K) | 6.3 | 10.7 | 0.95 |
| Magnesium (Mg) | 3.3 | 5.6 | 0.50 |
| Sulphur (S) | 1.3 | 2.2 | 0.20 |

***Cows feel very comfortable lying down on compost.***
Using compost as a boxstall cow-bed is 50 -75% cheaper, when compared to other bedding material:

| **Bedding material** | **Quantity / cow** | **Cost / cow** | **Somatic Cell count ('000)** |
|---|---|---|---|
| Compost | 600 kg / yr | $35 | 285 |
| Digestate | 900 kg / yr | $30 | 120 |
| Sawdust | 800 kg / yr | $140 | 206 |
| Straw | 350 kg / yr | $100 | 210 |
| Sand | 1,300 kg / yr | $14 | 161 |

Compost or digestate has a future off-farm as a product. Society is becoming greener every year. Compost or digestate has a future as bedding in stalls, but also for the rooftop garden industry. Compost or digestate has a future off-farm, provided it doesn't go at the cost of carbon on the farm. As Rudolf Steiner said in 1925' "The farm is a living organism". Every kilogram of carbon removed from the farm must be replaced, in order to keep the farm sustainable".

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