

HOW TO INTERPRET A COMPOST ANALYSIS REPORT

By Keith Reid, Amber Dort, Lindsay Scott, and Rosalie Gillis-Madden

Introduction: Why Compost?

Compost could be considered any decayed organic material used to provide nutrients to plants. For land applications, it is more useful to use the more specific definition from the U.S. Composting Council: a “product manufactured through the controlled aerobic, biological decomposition of biodegradable materials. The product has undergone mesophilic and thermophilic temperatures, which significantly reduces the viability of pathogens and weed seeds ... and stabilizes the carbon such that it is beneficial to plant growth...” (USCC, 2022). Using compost on your farm has several advantages:

- The bulk of the material and the moisture content are reduced during the composting process, so costs for transportation and application are less.
- Properly composted materials should have low levels of pathogens or weed seeds.
- Nutrients in the compost have been stabilized, so there is less chance of volatile losses (and less smell). The organic carbon has also been converted to more stable forms, so more of the added carbon will remain in the soil.
- Nutrients in compost can replace mineral fertilizer and reduce input costs for crop production.

In addition to direct benefits to the compost user, there is a societal benefit as composted materials from non-agricultural sources recycle nutrients and carbon back into the soil, turning wastes into beneficial products.

To realize these advantages, knowing what is in the compost you are planning to apply is critical. The variety of materials used as compost feedstocks results in a wide variation in compost quality. **Having a compost analysis report, and knowing what it means, is the best way to maximize the value of your compost applications.**

Understanding your compost analysis will also help you avoid the pitfalls of applying high rates of compost to build soil organic matter without accounting for the nutrients in that compost. This can lead to unneeded expense for fertilizer applications, reduced crop yields or quality through excess or imbalanced nutrients, or harmful nutrient losses to the environment. Applying an inch of compost to the surface as a mulch, for example, means an application rate of 40 or more tons/acre. With this amount of material, even if the nutrient density is low, there are a lot of nutrients applied.



Compost Basics

Two compost categories have been created to help guide compost usage: Category A compost (unrestricted use) and Category B compost (restricted use). This factsheet deals strictly with Category A compost, which can be used on agricultural lands and in the nursery industry. A compost must have acceptable levels of heavy metals and foreign objects to meet the Category A criteria. More information on these limits can be found in the Canadian Council of Ministers of Environment Guidelines for Compost Quality (2005). This factsheet focuses on land applications of compost as a soil amendment and nutrient source.

A wide range of feedstock materials can be used, such as plant residue, municipal solid waste, food processing waste, municipal biosolids, pulp or paper mill biosolids, or manure. This range of feedstocks results in an equally broad range of nutrient concentrations and, therefore, value for different agricultural purposes.

Compost Analysis

To optimize fertility management and to ensure a safe product is being used, it is recommended that prior to field application, a compost analysis is conducted. Most compost retailers will have an analysis of their product that they will provide upon request; however, sometimes, this yields insufficient information. Many labs analyze compost; here are some things to look for and be aware of when reading a lab report.

Most labs will provide numerical values for nutrients and organic matter, percent dry matter and/or percent moisture, carbon to nitrogen ratio (C:N), and pH. It is always important to pay attention to units, as different labs will provide measurements using different units. Sometimes, a conversion must be performed to assist with understanding the parameters (Table 1).



Table 1. Common conversion factors.

1. %DM/100 X dry basis % = as applied %
2. ppm/10,000 = %
3. % P X 2.29 = % P₂O₅
4. % K X 1.2 = % K₂O
5. % X 10 = kg/T (metric tonne)
6. % X 20 = lb/ton (US ton)
7. 1 mS/cm = 1 dS/m = 1 mmhos/cm

Dry Matter

A lab report will typically tell you the percent dry matter. The inverse of this is percent moisture (100% – % dry matter = % moisture). The higher the percent dry matter, the dryer the product is. The percent dry matter often comes into play when determining the amount of nutrients in the compost (Example 1). Typically, nutrient values will be reported on a dry weight basis, but it is worth inquiring if the report does not say. This is an important distinction when calculating fertilizer value.

Example 1. Determining nutrient content of your compost pile.

If a compost is 40% dry matter and the sample is 2% nitrogen (dry weight basis), it is only 0.8% nitrogen as-applied (dry matter * dry-weight basis measurement = as-applied measurement). Applying 10,000 lbs (5 tons) of compost as it comes off the pile will give you 80 lbs of nitrogen, not 200 lbs of nitrogen.

C:N Ratio

The carbon to nitrogen ratio (C:N) of a compost will affect nutrient cycling and if and how quickly some of the nutrients in the compost will become available to the crop. Depending on the feedstock, the C:N ratio can vary in a compost material but typically ranges from 8:1 to 30:1. Applying composts that have a C:N ratio of greater than ~40:1 will result in “tying up nitrogen” – as microorganisms break down carbonaceous material, they require more nitrogen than what is found in the compost and will “rob” the surrounding soil (and your crop) of nitrogen in order to decompose the compost. This can result in nitrogen deficiencies in your crop. A C:N ratio in the teens or low twenties usually means there is more

nitrogen in the compost than the microorganisms need, and so it will become plant-available more readily. Soil applied compost with a C:N in the mid-20s to low 30s will become slowly plant-available over the years (See Table 2).

Nutrients

Typically, finished composts provide low levels of nutrients, although this will vary with the feedstock used to produce the compost. Compost's main impact on soil fertility is increasing organic matter and improving soil microbial life to assist in nutrient cycling. Much of the nitrogen in composts is converted to more stable organic forms during the composting process and is slowly available. However, phosphorus, potassium, and most micronutrients in compost should be readily available.

With high application rates, caution must be taken that you are not applying some nutrients in excess.

A balance of nutrient sources that target crop needs is always advised.

Nitrogen

Nitrogen can take many forms in compost. "Organic nitrogen" refers to nitrogen that is part of microbial bodies or part of plant or animal tissue. The organic form of nitrogen is typically not plant-available. Organic nitrogen needs to be "mineralized" to become plant-available. This means that the microbes need to process the organic nitrogen, and when the microbes excrete or die, that organic nitrogen is turned into its mineral form. The mineral forms of nitrogen that are plant-available are ammonium-nitrogen ($\text{NH}_4\text{-N}$) and nitrate-nitrogen ($\text{NO}_3\text{-N}$). The mineralization rate will vary with the C:N ratio of the compost (faster with low C:N ratios, slower with high), as well as the weather (fastest under warm, moist conditions but delayed by cold or dry soils). One of the challenges with using compost as the only source of N for the crop is that the release of N may not match the time when the crop needs it. Slow, steady mineralization of the organic N may not provide enough available N during the rapid growth phase of the crop when N uptake is greatest. Additionally, that N might continue to be released later in the season after the crop has been harvested. Pairing composts with cover crops can help ensure this does not become an environmental risk. The N content of your compost can be presented in several ways on a compost analysis.

Total Nitrogen (N)

The total nitrogen analysis will include the organic N in the compost, plus some or all the mineral N in the sample, depending on the analysis used.

A reminder: organic nitrogen needs to be broken down (mineralized) to release ammonium-N before it is available to crops.

Ammonium Nitrogen ($\text{NH}_4\text{-N}$)

Ammonium is a mineral form of N that is rapidly available to plants. In livestock manure, ammonium is the dominant form of mineral N, but in finished compost, the majority of this has been converted to nitrate. One of the measures of compost maturity is the ratio of nitrate to ammonium, which should be much greater than one. However, many labs use the same analytical methods for compost as for manure and only include the $\text{NH}_4\text{-N}$ values. It is recommended that you look for a lab that will also include nitrate analysis.

Ammonium will volatilize into the air if the compost is applied to the soil surface and left there. One of the advantages of compost is that this volatile loss is less than from raw manure because most of the ammonium has been converted to organic or nitrate forms.

Nitrate Nitrogen ($\text{NO}_3\text{-N}$)

Nitrate is also a mineral form of N, and it is the dominant nitrogen compound taken up by plants because it moves easily with water and can be easily absorbed by plant roots. This also means that nitrate that is applied at times of the year when plants are not actively absorbing N can be lost through leaching or denitrification. Leaching occurs when drainage water carries nitrate below the rooting zone. Denitrification is the process by which nitrate is converted by microbes into gaseous forms that are lost from the soil. Increased denitrification can lead to poor nitrogen use efficiency on your field, resulting in unwanted losses of nitrogen (and money). Denitrification also creates nitrogen (N_2) gas and nitrous oxide (N_2O), the latter which can contribute to climate change.

Ignoring the $\text{NO}_3\text{-N}$ fraction of nitrogen in compost will underestimate the nutrient availability of the compost and could result in overapplication of N. Depending on the crop and the soil, this represents a loss in profit through unnecessary fertilizer expense or loss of crop yield or quality, as well as a potential environmental impact.

Forms of Nitrogen

Calculating Nitrogen Availability from Compost Analyses

The nitrogen that gets to the crop from a compost application comes from two pools: the mineral N ($\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$) and the mineralization of the organic N. The mineral N is immediately available, the same as fertilizer ($\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ are the same compounds found in conventional fertilizer). However, mineral N is also lost from the soil if not taken up by plants soon after application. Some of the $\text{NH}_4\text{-N}$ will be retained over the winter if compost is applied in the fall since it will bind to the soil, but assume that all the $\text{NO}_3\text{-N}$ in fall-applied compost is lost either through leaching or denitrification. For compost applied immediately before planting in the spring, all the $\text{NO}_3\text{-N}$ will be available to the crop along with the $\text{NH}_4\text{-N}$ that is not lost to the air through volatilization. Where possible, composts with high N contents should be applied in the spring before planting.

There is considerable uncertainty around nitrogen release from the organic pool. This uncertainty stems from differences both in application timing and the nature of the compost. Table 2 presents some general guidelines for N availability to plants, but should be combined with your observations of crop responses. A challenge for many users is that many compost analyses do not include nitrate-N, so the contribution of this fraction is uncertain. As a general rule, the nitrate concentration of compost will increase along with the total N.

Application Timing Matters... Somewhat

When you apply compost will affect how much N is available, depending on how much N is in the compost. Low N composts will have very little mineral N, and need to break down before the organic N becomes available; these materials are better applied in the fall so the N release happens when the next crop needs it. High N composts will carry a fair amount of $\text{NO}_3\text{-N}$, which is immediately available to the crop. Applying a high N compost in the fall may provide about the same N to the crop as a spring application, because the organic N will mineralize, but the $\text{NO}_3\text{-N}$ will have been lost over the winter. This is a waste of money, as well as a potential environmental risk.

Composts do not vary as much in nutrient availability due to application timing as raw manures.

Table 2. Estimates of plant available N from composts, both as a fraction of total N, and as a fraction of organic N in the compost.

Analyses		Estimated plant available N from compost during the first year after application	
C:N Ratio	Total N (% dry wt.)	% of compost total N	% of compost organic N
Below 10:1	Above 2	10	5
10:1-20:1	1-2	5	2
Above 20:1	Below 1	0	0

Note that at very high C:N ratios (>30:1), the compost can immobilize both the mineral N in the compost and mineral N present in the soil. These materials should not be applied in the spring to crops with high N requirements.

Phosphorus

The phosphorus nutrient value on a compost lab analysis may be presented as % P, % P_2O_5 , ppm P or ppm P_2O_5 . The fertilizer value of phosphorus is represented as P_2O_5 . If the results are presented as P only, you must multiply that value by 2.29. For example, an analysis that presents 400 ppm P is really 916 ppm (or ~0.09%) P_2O_5 (Example 1, 2).

There is a maxim among crop advisers that “manure is great for building soil P, but terrible for feeding the crop.” Compost will fall into this same category. Similar to manure, it is bulky enough that it cannot produce the same concentration of P in a band near the seed where it is needed most, like you can do with mineral fertilizer. Some of the P compounds in manure are slow to break down into available forms. **Reducing the P fertilizer rate by approximately half the amount added as compost is a reasonable target.** The exception will be for composts derived from sewage biosolids treated with chemical precipitants to facilitate P removal from wastewater. These materials will have much lower P availability in the short to medium term. With any compost application, regular soil tests will help to monitor the impact on the availability of P to crops.

Watch the total P application rates with compost, particularly if it is applied primarily to supply nitrogen to crops. In the fish waste compost (Example 2), if the compost was applied at 2 tons/acre, it would supply about 73 lbs/ac of P_2O_5 . If all of the N requirements are met through compost, the P application can be much greater than what is removed by the crop resulting in significant build-up of P soil test values and the risk of elevated P in runoff.

Example 2. Sample calculation of P fertilizer adjustment.

Seamus is growing a field of barley, and his soil test calls for applying 55 kg/ha (50 lb/ac) of P_2O_5 . He has managed to source compost from the local fish plant that has a total P concentration of 0.8% P (as applied), which he plans to apply at 2 tons/acre.

Total P in compost = 0.8%

P_2O_5 in compost = $0.8 \times 2.29 = 1.83\% P_2O_5$

P_2O_5 applied = 4,000 lbs compost \times 1.83% = 73 lb/ac

P fertilizer rate should be reduced by approximately half the amount added as compost-P: $(50 - 36.5) = 13.5$ lb/ac

Seamus should plan to apply $(50 - 36.5 =) 13.5$ lb/ac of P_2O_5 fertilizer to meet the rest of his crop needs.

Potassium

The potassium nutrient value on a lab analysis may present results as % K, % K_2O , ppm K or ppm K_2O . The fertilizer value of potassium is represented as K_2O . If the results are presented as K only, you must multiply that value by 1.2 to get K_2O . For example, an analysis that presents 400 ppm K is 480 ppm (or ~0.05%) K_2O (Table 1).

Potassium in compost will be in its soluble form, and so it can be considered to be as available to plants as mineral fertilizer.

Salts

Soluble salts are often reported as part of the compost analysis. This may be reported as “soluble salts” or as “electrical conductivity (EC).” It is a measure of the soluble ions, which encompasses both beneficial salts, which are also plant nutrients, such as potassium (K^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), nitrates (NO_3^-), and ammonium (NH_4^+); as well as salts that are less beneficial to plant life such as sodium (Na^+) and chloride (Cl^-).

If the soluble salt concentration is high, even “good” salts may cause damage to plants, but if diluted in the soil, the compost would be an excellent source of nutrients. Soluble salts in composts will generally not be a risk when applied at agronomic rates and incorporated into the soil. Still, they could be a concern where there is a combination of high EC (>10 dS/m) and high application rates repeated over several years. The units for reporting EC may be dS/m, mS/cm or mmhos/cm; the numbers for each are identical $1 \text{ dS/m} = 1 \text{ mS/cm} = 1 \text{ mmhos/cm}$.

Sodium

Sodium (Na) concentrations can be high in composts derived from food processing wastes or marine vegetation. While extreme levels of Na can be toxic to plants, this is extremely rare in field applications because of buffering in the soil. A more common concern is that Na accumulations in the soil can cause soil structure to break down, reducing water infiltration and increasing the risk of crusting, erosion, or compaction. Care should be taken if the Na concentration in the compost is greater than the combined concentration of Ca and Mg (Ca + Mg).

Compost for Increasing Soil Organic Matter

In addition to providing nutrients to your crop, compost application can improve soil health by increasing soil organic matter, enhancing soil tilth, improving soil structure, and increasing water retention (Rynk et al., 1992). Building soil organic matter means increasing the amount of carbon in the soil. Soil organic matter is roughly 50% carbon, which means that for every 1% organic matter in your soil, you have 0.5% organic carbon (Example 3). In a changing climate, using soil as a carbon sink ultimately reduces greenhouse gas emissions, mitigating climate change. Building soil carbon is also a climate change adaption strategy – healthy soils with good levels of organic matter are more drought tolerant, have better drainage, and are more resilient in the face of disturbances such as extreme weather events (Favoino and Hogg, 2008; USDA NRCS, 2011).

Example 3. How much carbon is in your soil?

The top six inches of soil in a field is referred to as an acre furrow slice, which weighs ~2,000,000 lbs. If your soil test shows 3% soil organic matter, that means that you have 60,000 lbs of soil organic matter per acre, which is 30,000 lbs of soil carbon per acre. That's the same as two school buses!

Soil organic matter is constantly in flux, which means there are organic matter additions (i.e. compost, crop residue, cover crops, manure, etc.) and subtractions (microbial respiration, erosion, etc.) If there are no carbon inputs into the soil, soil organic matter decomposes at the rate of about 3% per year (see Example 4). As a rough guideline, approximately 20% of added carbon remains in the soil after one year. That means that if you add 1000 lbs of carbon in the form of manure or crop residue (e.g. about 8 tons/acre of farmyard manure, depending on the exact carbon content), roughly 200 lbs of carbon will remain in the soil the following year (Magdoff and Van Es, 2021). Compost will behave differently from fresh materials, primarily because the easily degraded organic carbon has been consumed during the composting process, leaving compounds in the compost that are more resistant to breakdown. There are estimates that organic C from composts may contribute up to twice as much to soil organic carbon as the equivalent from fresh manure or crop residues (Nisar & Benbi, 2020).

Example 4. How do you maintain soil carbon?

If you start with 3% soil organic matter, and soil organic matter decomposes at a rate of 3% per year, if you make no carbon additions, in 14 years, your soil organic matter will have fallen to 2%.

To maintain your soil organic matter at 3%, you will need to annually add 4,500 lbs of carbon (which will leave 900 lbs of stable carbon after the first year, which is 3% of the 30,000 lbs of soil organic carbon) per acre (i.e. crop residue, cover crops, composts, manures, etc.) If you are starting at a base of 4% soil organic matter, you will need to annually add 6,000 lbs of carbon per acre. Some of this will come from crop residues, but most soils will need additional carbon in the form of cover crops, manure or composts to maintain or build organic matter (Figure 1).

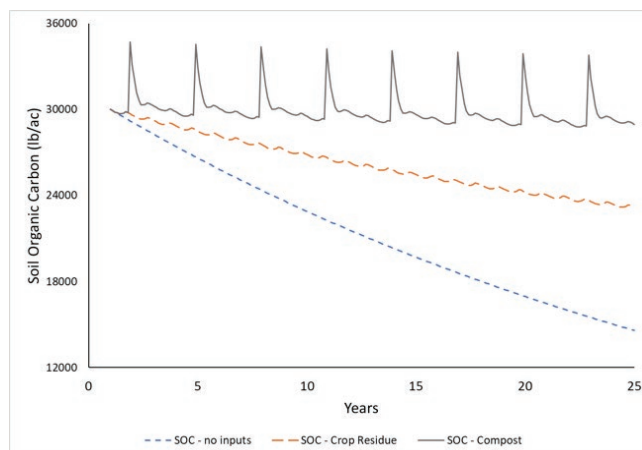


Figure 1. Soil organic carbon will decline if not replenished. Crop residues will do part of this, but applying approximately 20 tons/acre of compost once every three years will maintain soil carbon levels.

Other Parameters

Several other parameters are included in a compost analysis report to determine if the compost meets the criteria for Category A (unrestricted use). It may be helpful to understand what they are.

Heavy Metals

Heavy metals in the compost feedstock can accumulate as they are not broken down during the composting process. Small amounts of these trace elements are permitted in Category A compost; maximum concentrations can be found in Table 3. If concentrations exceed these levels, there is a risk that they could

accumulate in the soil or in plants growing in the soil, so there are limits to how much could be applied or if it can be used for land applications at all.

Table 3. Trace element maximum concentration as outlined in the "Support Document for Compost Quality Criteria [National Standard of Canada CAN/BNQ 0413-200, Canadian Council of Ministers of the Environment (CCME) Guidelines and Agriculture and Agri-Food Canada (AAFC) Criteria."

Heavy Metal	Canadian Maximum Limits for Dry Compost (mg/kg dry weight) *
Arsenic (As)	13
Cadmium (Cd)	3
Chromium (Cr)	210
Copper (Cu)	400
Cobalt (Co)	34
Lead (Pb)	150
Mercury (Hg)	0.8
Molybdenum (Mo)	5
Nickel (Ni)	62
Selenium (Se)	2
Zinc (Zn)	500

* 1 mg/kg = 1 ppm

While it might appear startling to have some of these compounds, such as arsenic, in your compost, they are all naturally occurring minerals found in the earth's crust and many soils. For example, in Nova Scotia, fairly high arsenic levels occur naturally in our soils and water. As plants grow, they take up some of the arsenic. In the composting process, these minerals are concentrated, sometimes to levels that are unsafe to use for agricultural purposes. Arsenic is often found in wood ash for similar reasons.

Foreign Matter

This is the inorganic stuff that gets into the compost but won't break down in the soil (plastic, glass, metal, etc.), some of which might be sharp enough to cause injury or puncture tires. Category A compost should not have any sharp foreign matter greater than 3 mm per 500 mL sample. Neither should it have more than one piece of foreign matter greater than 25 mm per 500 mL.



Figure 2. Example of a foreign object that should have been excluded from compost that has created problems for food crops.

Compost Maturity and Stability

Compost that isn't mature could smell, attract flies, or, depending on the C:N ratio, rob your soil and crop of nitrogen. The Canadian Council of Ministers of the Environment Guidelines for Compost Quality outlines parameters for a compost to be considered mature and stable as follows:

Must be cured for a minimum of 21 days and meet one of the three following requirements

1. Oxygen (O₂) uptake respiration rate is less than or equal to 400 mg of oxygen/kg of organic matter/hour
2. Carbon dioxide (CO₂) respiration rate is less than or equal to 4 mg of carbon in the form of carbon dioxide/gram of organic matter/day
3. The temperature rise of the compost above ambient temperature is less than 8°C (i.e., the compost no longer heats up significantly)

A complete compost analysis will usually provide a measurement of compost maturity and stability.

Pathogens

It is widely assumed that composting will reduce the concentration of pathogenic bacteria from the feedstocks due to heating during the active phase of composting and competition from other microbes during the maturation phase. These processes are not perfect, however, so composts are tested for the presence of pathogenic bacteria. Fecal coliforms are an indicator of contamination by feces and, therefore, the risk to human safety. Salmonella is one pathogenic species of bacteria measured directly. Acceptable levels for these bacterial indicators are outlined below in Table 4.

Table 4. Acceptable levels of indicator organisms in compost based on compost type and categorization (Government of Canada, 2021 & Guidelines for Compost Quality, 2005).

Compost Type	Indicator Organism	Level
Fertilizers and Supplements	Fecal coliforms	<1000 MPN (Most Probable Number)/gram solid
Fertilizers and Supplements	<i>Salmonella</i>	Not detectable
Yard Waste and/or Other Feedstock	Fecal coliforms	<1000 MPN/g of total dry weight solids
Yard Waste and/or Other Feedstock	<i>Salmonella</i>	<3 MPN/4g of total dry weight solids

Food Safety

It is the producer's responsibility to be informed about the contents and quality of the compost that is being applied to their soil, especially if crops are being grown for human consumption, where food safety should be a top priority. By effectively managing manure and compost, you can reduce the possibility of pathogen contamination and ensure the food grown stays safe to consume.

Most Food Safety programs and Canadian organic certification recommendations require that an organic-based amendment such as manure or compost be applied and incorporated into the soil for 120 days before harvest. It is best practice for any organic amendment (particularly if it may be only partially composted) to be incorporated into the soil at least 120 days before harvesting if the crops have edible parts that may touch the soil, or at least 90 days before the harvest of crops that do not come into contact with the soil and are intended for human consumption (K: PSL for crop production (311 clause 4), 2020).

When applying animal manure to the soil, properly composting it before application can kill most of the microorganisms which could cause disease in humans and other animals and plants. If you are composting on-farm, the *entire* compost pile should reach a temperature of 55°C (130°F) for at least four days.

If you purchase manure or compost, ask questions about the composting process, or get a certificate of analysis for the product. Commercial compost producers may have to meet additional criteria under the Fertilizers Act, and it is their responsibility to understand and follow these regulations.

Summary

Compost is an excellent material for supporting soil health and providing nutrients to crops, but the material is variable and having a lab analysis can help maximize the value of your soil amendments. The nitrogen availability in the compost will vary depending on the C:N ratio, with lower availability from materials with higher C:N. The phosphorus, potassium and micronutrients in the compost will add to the store of plant available nutrients in the soil and could be an environmental concern if high rates of compost are added. Compost can be an excellent addition for building soil organic matter and soil carbon.

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