SOURCES OF NUTRIENTS

Most of the nutrients taken up by plants are supplied by the soil itself. Sometimes, the levels of particular nutrients in soil are too low to support adequate growth.

As discussed earlier, materials that can be added to the soil to supply nutrients are either inorganic (such as commercial fertilizers) or organic (crop residues, manures, and biosolids). There are many types of either kind, each with its own special properties, and pros and cons relating to cost, practicality, safety, and environmental protection.

The information in this chapter should help you develop a nutrient management program by:

- describing the sources of fertilizer materials and their fate in the soil
- assessing the materials you are using now, and materials you may consider using.

NUTRIENT TERMINOLOGY

Except for phosphorus and potassium, the nutrient content of most materials is expressed as the concentration by weight (percentage, parts per million, pounds per ton, kilograms per tonne, etc.) of nutrients in their elemental form – not in combination with other elements.

Phosphorus requirements and the phosphorus content of fertilizers are expressed as phosphorus in the pentoxide form, P_2O_5. Potassium is expressed as K_2O.

The available nutrient content of fertilizer is called its analysis or grade. It's shown as the percentage of nitrogen, P_2O_5 and K_2O, respectively. For example, 8-32-16 contains at least 8% (total) nitrogen, 32% (available) P_2O_5, and 16% (water-soluble) K_2O.

NUTRIENT CONTENTS OF COMMON FERTILIZER MATERIALS

MATERIAL	N (%)	P_2O_5 (%)	K_2O (%)	Ca (%)	Mg (%)	S (%)	Cl (%)
NITROGEN MATERIALS							
Ammonia, anhydrous	82	—	—	—	—	—	—
Ammonium nitrate	34	—	—	—	—	—	—
Ammonium sulphate	21	—	—	—	—	23.7	—
Calcium nitrate	15	—	—	19.4	1.5	—	—
Calcium ammonium nitrate	27	—	—	4	2	—	—
Sodium nitrate	16	—	—	—	—	—	—
Urea	46	—	—	—	—	—	—
UAN solutions	28–32	—	—	—	—	—	—
PHOSPHORUS MATERIALS							
Single superphosphate	—	20	—	20	—	12	—
Triple superphosphate	—	46	—	13.6	—	1.4	—
Bonemeal	2–4	*	—	20–25	—	—	—
Rock phosphate	—	*	—	33	—	—	—
POTASSIUM MATERIALS							
Potassium chloride (muriate)	—	—	60–62	—	—	—	47
Potassium-magnesium sulphate	—	—	22	—	11	22.7	1.5
Potassium sulphate	—	—	50	—	1.2	17.6	2.1
MULTIPLE NUTRIENT MATERIALS							
Diammonium phosphate (DAP)	18	46	—	—	—	—	—
Monoammonium phosphate (MAP)	10–13	48–52	—	—	—	—	—
Gypsum	—	—	—	22.5	—	16.8	—
Limestone, calcitic	—	—	—	25–40	0.5–3	—	—
Limestone, dolomitic	—	—	—	19–22	11–13	—	—
Magnesium sulphate	—	—	—	2.2	10.5	14	—
Potassium nitrate	12	—	44	—	—	—	1.1
Sulphur	—	—	—	—	—	30–99	—
Wood ashes	—	1.8	5.5	23.3	2.2	—	—

*these materials are highly variable in phosphorus availability

MINERAL FERTILIZERS

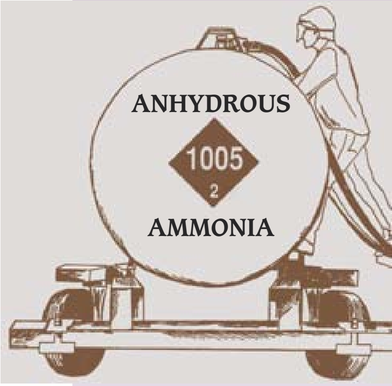
COMMON FERTILIZER MATERIALS

Commercial fertilizer materials are one of the major sources of nutrients for crops. Here are some of their advantages and disadvantages.

MINERAL FERTILIZERS	
BENEFITS	**SIGNIFICANCE**
• nutrients are concentrated in materials with consistent physical characteristics	• fertilizer materials are generally easy to transport, handle, and apply evenly and accurately
• nutrient content is known and consistent	• blends can apply nutrients to match crop needs based on soil tests, without the need to apply nutrients that are already present in adequate amounts
• nutrients are generally available quickly (or with predictable release for enhanced fertilizers)	• timing of application can be flexible, to match nutrient supply to crop uptake • overapplication of very soluble fertilizers can lead to crop injury
CHALLENGES	**SIGNIFICANCE**
• materials are made from non-renewable resources	• proper stewardship is necessary
• some materials, e.g., anhydrous ammonia, can cause injury	• these materials require special handling precautions to be applied safely

Anydrous ammonia is the first product generated during nitrogen fertilizer processing.

Handling nitrogen materials requires strict safety measures.



Nitrogen

Most of the materials used as nitrogen fertilizers are manufactured from the nitrogen gas in air and natural gas. Anhydrous ammonia (82% N) is the first product from this process. Most other commonly used nitrogen materials are then manufactured from ammonia.

Because ammonia requires the least amount of manufacturing, it costs less per unit of nitrogen than any other nitrogen fertilizer material. However, safety and handling costs are higher than for other materials. For a detailed comparison of nitrogen materials, refer to OMAFRA Publication 611, *Soil Fertility Handbook*.

The Steps in Manufacturing Nitrogen Fertilizers

natural gas	PLUS	nitrogen gas	=	anhydrous ammonia (82% N)
ammonia	PLUS	oxygen	=	nitric acid
ammonia	PLUS	carbon dioxide	=	urea (46% N)
ammonia	PLUS	nitric acid	=	ammonium nitrate (34% N)
ammonium nitrate	PLUS	urea		
	PLUS	water	=	UAN solution (28–32% N)

Most products designed to enhance the efficiency of N uptake delay the release of its soluble forms, ammonium and nitrate. The products fall into one or more of the following categories:

- **slow or controlled-release fertilizers** – materials that contain N in a form that delays its availability for plant uptake, and thus makes it available over a longer period of time, in comparison to the regular ammonium, nitrate or urea fertilizers. The delay in release can be attained by a polymer (e.g., ESN®) or sulphur coatings, or incorporation into insoluble or organic compounds.
- **urease inhibitors** – a substance that inhibits the hydrolytic action on urea by the urease enzyme. An example is Agrotain®, which contains N-(n-butyl) thiophosphoric triamide (NBPT).
- **nitrification inhibitors** – a substance that inhibits the biological oxidation of ammonium to nitrate. Examples include N-Serve® (nitrapyrin) and DCD (dicyandiamide).
- **stabilized fertilizers** – fertilizers with substances added that extend the time the fertilizers remain in the urea or ammoniacal form. An example is SuperU®, a urea fertilizer containing both NBPT (a urease inhibitor) and DCD (a nitrification inhibitor).

Anhydrous ammonia is usually the least expensive fertilizer material per unit of nitrogen.

Phosphorus

Rock phosphate is insoluble in water and the phosphorus it contains becomes available to plants very slowly – taking 100 years or more. Common phosphorus fertilizer materials are made by treating rock phosphate with various acids.

Products designed to enhance efficiency of P uptake delay the fixation of P by the soil. These may include organic or humic materials, and polymer coatings that reduce the rate of diffusion from the granule to the fixation sites in the soil. One example is a grade of 11-52-0 monoammonium phosphate coated with maleic itaconic copolymer (AVAIL®) that is being marketed in North America.

Some deposits of phosphate rock are high in heavy metals like cadmium. The Fertilizer Act sets limits on the maximum concentration of heavy metals in fertilizers, such that applying the maximum recommended rate of any fertilizer for 45 years would not appreciably increase the concentration of that metal in the soil. The heavy metal concentration in the deposits of phosphate in Florida is very low.

Rock phosphate, which is mined mainly in the southern United States, northern Africa and Russia, is the source of almost all of the phosphorus in fertilizers.

Fertilizer Materials Made From Phosphate

Rock phosphate plus sulphuric acid produces:
- single superphosphate (0-20-0) or phosphoric acid.

Rock phosphate plus phosphoric acid produces:
- triple superphosphate (0-46-0).

Phosphoric acid plus ammonia produces:
- mono-ammonium phosphate (11-52-0) or diammonium phosphate (18-46-0).

Superphosphoric acid plus ammonia produces:
- ammonium polyphosphates, fluid (11-37-0).

The most common source of potassium is potassium chloride, also called muriate of potash (60% K_2O), and is mined in Saskatchewan, New Brunswick, and the United States.

Potassium

Muriate of potash requires little processing; the ore is simply crushed into granules of potassium chloride and sodium chloride, which are separated by flotation in brine.

Other sources of potassium include:

- ► potassium sulphate (50% K_2O)
- ► potassium nitrate (44% K_2O)
- ► sulphate of potash-magnesia (22% K_2O).

ORGANIC SOURCES

Many organic materials can be used to supply nutrients to cropland. These include crop residues and livestock manures and composts. Biosolids and other "non-agricultural source materials" (NASMs) approved by Ontario Ministry of the Environment can also be used.

ORGANIC NUTRIENT SOURCES

BENEFITS	SIGNIFICANCE
• contain many macronutrients and micronutrients	• a good single source of many nutrients for your soil
• supply organic matter to the soil	• soil structure improvement • increased nutrient- and water-holding capacity • improved drainage
• provide nutrients for crops over several years after application	• not all nutrients are immediately available – some of them are tied up in organic forms ○ over time, this material breaks down to available (inorganic and soluble) forms
• create an opportunity to close the loop in urban and rural nutrient cycling	• crop nutrients leave the farm in the form of fruits, vegetables, grains, and animal products for human consumption • organic nutrients in the form of sewage biosolids and other NASMs can be returned to the soil • the need to dispose of these wastes by landfilling or burning is reduced • organic nutrient sources are treated as resources – not wastes to be disposed of • for minimal costs, other than time and energy, most of these nutrients can be applied with readily accessible equipment

Every effort should be made to apply manure evenly. For more info on BMPs for application, please see the BMP book *Manure Management*.

Adding organic material to soil can bring many benefits. However, it's really important to test organic materials so you know exactly what nutrients they contain. **See pg. 73 for more information.**

Manure and biosolid application systems often have high axle loads, risking soil compaction.

LIVESTOCK MANURES

Although storage, handling, and spreading of manure can pose several problems on livestock farms, manure is a valuable resource. Nutrients retained on your farm reduce both the risk of damage to the environment and the cost of what might otherwise have to be spent on commercial fertilizers.

The nutrients in manure as they pertain to crop removal are significant. See the chart on pg. 26.

Variable Nutrient Content

Manure consists of undigested feed, plus bedding, wasted feed, and/or water. Depending on the type of livestock and the ration being fed, fresh manure can contain:

- up to 80% of the nitrogen originally present in feed
- up to 75% of the phosphorus originally present in feed
- 80 to 95% of the potassium originally present in feed.

The average nutrient contents of several types of manure are shown in the next table. Contents of individual samples, however, may range from one-tenth of the average to double the average! Be aware of the wide range in the nutrient contents of manure – use of average values often results in applications of nutrients that don't match crop requirements.

Nutrient contents of organic materials are usually reported as percentage by weight of the elemental form (e.g., %N, %P, %K).

Phosphorus and potassium must be converted to P_2O_5 and K_2O respectively. Ammonium-nitrogen and micronutrient contents are usually reported in milligrams per kilogram (mg/kg) or milligrams per litre (mg/l).

To convert:

- mg/kg to pounds/ton, divide mg/kg by 500
- mg/l to pounds/1000 imperial gallons – divide mg/l by 100.

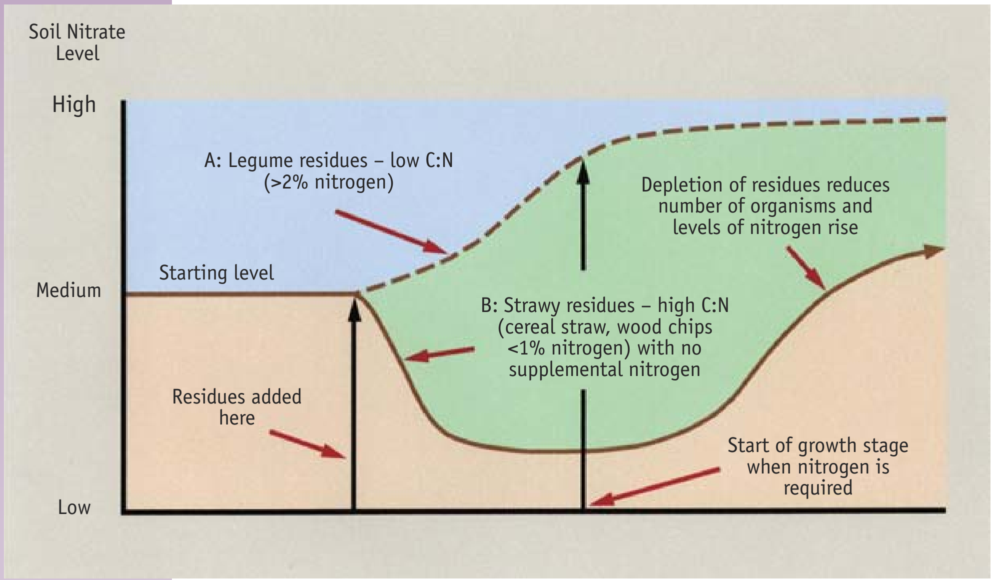
Test your manure regularly for nutrient content. It's the only way to obtain an accurate estimate.

Water

Large volumes of water are often added to manure, intentionally or otherwise, through cleaning of livestock equipment, leaks during livestock watering, groundwater entry, rainfall, or runoff. This dilutes its nutrient content and adds to the amount of material to be handled and to the cost of storage, hauling, and spreading.

Bedding

Bedding is another factor. Bedding increases the organic matter content of manure, but reduces the concentration of most nutrients, especially nitrogen. Cereal straw usually contains less than 1% nitrogen; wood shavings contain less than 0.2% nitrogen. In breaking down these materials, micro-organisms in the manure and soil tie up available nitrogen.



Shown here is the effect on available nitrate-nitrogen for crops when two kinds of residues are worked into the soil. When straw residues are added (B), the soil organisms multiply rapidly and use up most of the mineral nitrogen in the soil. After a few weeks, nitrate begins to appear and reaches a new high level. Legume residues (A, upper line) cause an increase in nitrate-nitrogen levels soon after they are added.

Where soil nitrogen levels are low, use of large quantities of bedding, especially shavings, can reduce the amount of nitrogen immediately available to the crop.

AVERAGE NUTRIENT ANALYSES OF LIVESTOCK MANURES

MANURE TYPE		DRY MATTER	TOTAL N[1]	NH_4-N	P_2O_5[2]	K	Ca	Mg	S	Zn	Cu	Mn
		Fresh Weight Basis										
		%	%	%	%	%	%	%	%	ppm	ppm	ppm
SWINE	liquid	3.8	0.40	0.265	0.13	0.17	0.12	0.06	0.06	85	30	22
	solid	29.8	0.90	0.258	0.47	0.56	n.a.	n.a.	0.14	172	103	n.a.
POULTRY	liquid	10.6	0.83	0.558	0.3	0.3	1.6	0.08	0.08	70	11	64
	solid	52.6	2.37	0.550	1.11	1.17	4.6	0.28	0.16	238	33	204
DAIRY	liquid	8.5	0.36	0.153	0.09	0.24	0.49	0.14	0.04	48	17	40
	solid	24.2	0.61	0.128	0.17	0.50	1.54	0.36	0.08	95	29	107
BEEF	liquid	7.95	0.52	0.179	0.13	0.43	0.7	0.3	0.04	57	14	61
	solid	28.6	0.73	0.101	0.23	0.57	1.5	0.41	0.09	129	36	112
SHEEP	solid	31.3	0.76	0.186	0.27	0.70	1.5	0.38	n.a.	170	20	140
HORSE	solid	33.41	0.42	0.068	0.13	0.36	1.7	0.56	n.a.	73	23	113

Data from manure analysis provided from Ontario laboratories collected between 1992 and 2004; micronutrient data were obtained from a smaller subset of data.

[1] Total N = Ammonium-N + Organic N

[2] %P = total phosphorus

Year of Application – Nitrogen

Crops are able to obtain only a portion of the nutrients applied in manure in the year of application.

ESTIMATED NITROGEN AVAILABLE FROM MANURE

CROP YEAR	NITROGEN AVAILABLE*
Application year**	40–60%
1st year after application	1–4%
2nd year	0.5–2%
3rd year	0.2–1%

* expressed as percentage of the total initially applied

** 80% for liquid poultry manure

Because a higher proportion of the nitrogen in poultry manures is present as ammonium-nitrogen, 75–85% of the nitrogen in poultry manures can become available in the first year.

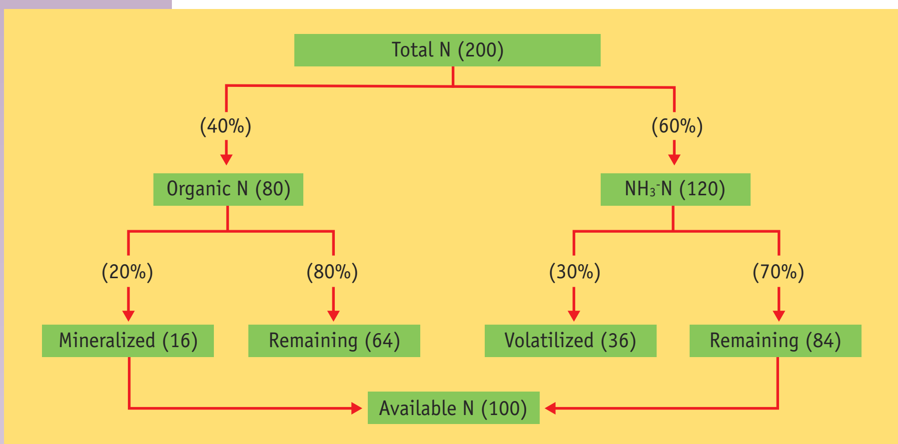
Nitrogen, in the ammonium form, is immediately available to crops, but typically at least 30% of it is lost. Up to 30% of the organic nitrogen becomes available in the first cropping year, depending on the type of manure and the amount of bedding used.

At best, 50–60% of the total amount of nitrogen from manure is available in the first crop-year after application.

Year of Application – Phosphorus and Potassium

Only 40% of the phosphorus in manure can be expected to become available as fertilizer phosphorus in the year of application. The balance of the phosphorus is absorbed by the soil, and will be reflected in the soil test value. Check your manure analysis report to verify the form of P being reported – available or total. It will have a profound impact on your calculations for nutrient balance.

Potassium is present in a soluble form and 90% of the total potassium in manure is available as fertilizer potassium in the year of application.



As the organic matter from manure breaks down in the years following application, it continues to supply nitrogen to the soil.

CROP RESIDUES

By returning crop residues to soil, you are:

- ensuring that part of the nutrients taken up by your crop is recycled
- helping maintain the organic matter content of your soil.

Residues left on or near the soil surface also help to reduce soil erosion.

PREVIOUS CROP	NITROGEN (LB/ ACRE)
Established forage – under 1/3 legumes	0
Established forage – 1/3–1/2 legumes	49
Established forage – over 1/2 legumes	100
Perennial legumes plowed in seeding year	40
Corn following red clover plowdown	73
Corn following red clover (no-tillage)	60
Corn following soybeans or edible beans	27
Corn following silage corn	12
Corn following cereals (straw removed)	11
Other crops	0

The Best Management Practices series has an entire book devoted to no-till practices.

The nitrogen fixed from air by some legume crops, especially the forage species, can add significantly to the supply of this nutrient in soil.

Residues from cereals and grasses tend to be low in nitrogen. Because soil micro-organisms require nitrogen to break down such materials, the supply of nitrogen available to crops can be temporarily reduced when large quantities are returned to the soil.

OTHER AGRICULTURAL MATERIALS

Nutrients are also found in other agricultural wastes such as washwaters, runoff from livestock yards and feed storages, and leachate from greenhouses and nurseries. The nutrient content of the material will depend on the conditions surrounding use and storage of the water.

These agricultural materials should be considered a nutrient resource and managed to maximize the benefit of their use.

Nutrients from washwaters need to be managed.

In Ontario, the application of sewage biosolids requires prior approval by the Ministry of the Environment.

NON-AGRICULTURAL SOURCE MATERIALS (NASMs)

SEWAGE BIOSOLIDS

Sewage biosolids from municipal sewage treatment plants can be a valuable addition to cropland.

To reduce the risk of biosolid runoff and to maximize nutrient utilization, restrictions are in place on the timing and location of the spreading of sewage biosolids and other NASMs. Sites to which biosolids are to be applied must be approved by the Ontario Ministry of the Environment.

To reduce the risk of contamination, a waiting period before harvesting of forages and fruit crops must be observed following biosolid application.

Unprocessed wastes from septic tanks, cesspools, and holding tanks cannot be used on cropland without approval from the Ontario Ministry of Environment.

Some factors considered in site approval for application of NASMs are:

- soil test for P
- soil pH
- slope of the field
- soil organic matter content
- natural soil drainage
- soil depth to bedrock
- snow cover and frost
- distance to wells, water table, watercourses, bedrock or homes.

Sewage biosolids are a good source of many nutrients, except potassium. Because the levels of phosphorus and zinc in sewage biosolids are often high, these materials can be an excellent means of correcting deficiencies of these nutrients in soil.

However, the high phosphorus content also means that levels of phosphorus in soils receiving sewage biosolids can be raised to undesirable levels.

In Ontario, most biosolids are produced by anaerobic digestion. These contain 3–9% nitrogen on a dry weight basis (dwb), of which 30–40% is in the ammonium form. De-watered biosolids contain less nitrogen (~ 4% of dry weight), because much of the soluble nitrogen is removed with the water.

Information regarding the use of sewage biosolids can be found in the publication, *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Lands*.

SAMPLE ANALYSIS OF ANAEROBIC SEWAGE SLUDGE*

Total solids	3%
pH	7.1

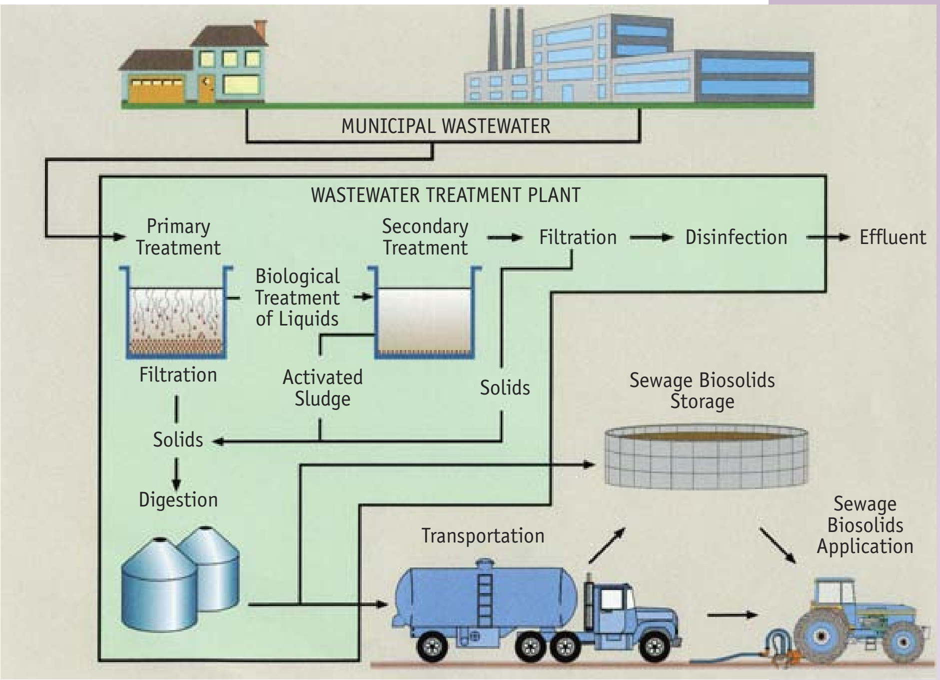
Nutrient content

Total phosphorus	3.67% (dwb)
Total nitrogen	6.5% (dwb)
Ammonium-nitrogen	2.3% (dwb)
Zinc	500 mg/kg
Potassium	trace

*sewage biosolids are also tested for arsenic, cadmium, cobalt, chromium, copper, mercury, molybdenum, nickel, lead, and selenium.

The nitrogen content of aerobic sewage biosolids is also lower than that of anaerobic sewage biosolids. Much of the nitrogen in aerobic biosolids is present in the organic form.

Guidelines for application rates of biosolids have been established to minimize the risk of contaminating soil with metals. Sewage biosolids are regularly analyzed for their content of the 11 regulated metals (see next page). Those that exceed the guideline for any one of these metals may not be applied to cropland.



Recycling processed sewage biosolids from municipal sewage treatment plants can provide cropland with valuable nutrients.

Heavy Metals

This term is used loosely to refer to a group of elements – mostly metals, with high atomic weight – that are of concern in the environment. These elements, if present at sufficient concentrations, can affect human or animal health, or they may reduce the growth of plants. Note that some of these elements are essential nutrients at lower concentrations. The harmful effect of these elements may be a direct toxicity, or may be due to competing with another essential element, creating a deficiency of that element.

The 11 regulated metals in Ontario are:

- Arsenic As
- Cadmium Cd
- Cobalt Co
- Chromium Cr
- Copper Cu
- Mercury Hg
- Molybdenum Mo
- Nickel Ni
- Lead Pb
- Selenium Se
- Zinc Zn

Heavy metals are often naturally occurring in soil, but may be at higher levels because of past additions of biosolids, industrial wastes, or pest control products. Of the 11 regulated metals, four are essential for both plants and animals, and three more are essential for animals. Further, these elements may provide growth-promoting benefits beyond the amount that is considered essential. Elevated metal concentrations in manure can occur if feeds have been supplemented with these elements. Elevated metals in sewage biosolids have traditionally been linked to industrial wastes, but strict sewer by-laws have almost eliminated this source in most municipalities. Biosolids that exceed limits for the regulated metals cannot be land-applied.

To view current compliance information regarding sewage biosolids (non-agricultural source materials (NASMs)) for the Nutrient Management Act, look up:
http://www.omafra.gov.on.ca/OMAFRA/index.html/nutrientmanagement

Sewage biosolids can add organic matter and nutrients to the soil. Follow the guidelines for proper handling and application procedures.

OTHER OFF-FARM SOURCES OF NUTRIENTS

Our society produces a wide variety of other waste materials. These include leaves, residential garbage, wood chips, paper, pulp, and food processing wastes. Many of these materials could be beneficial to soil as a source of organic matter and nutrients. Some wastes – cement kiln dust, for example – can also be used to correct soil pH problems, where appropriate.

The nutrient content of wastes depends on the materials from which they were made. Those derived from leaves, paper, or wood usually are low in nitrogen and may require supplementation to avoid inducing nitrogen deficiency in crops.

Because of the potential for contamination of the soil and environment, only waste materials approved by the Ontario Ministry of the Environment may be applied to approved sites.

Before a material will be approved, it must be demonstrated that:

- the nutrients or organic matter it contains will benefit the crop or soil
- it will not pose a risk to crops, soils, people, animals, or the environment.

Other guidelines relating to the use of NASMs on farmland are similar to those for sewage biosolids. (See *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Lands*.)

Other sources such as paper waste biosolids can provide organic matter and nutrients to soil.