

# Effects of some synthetic fertilizers on the soil ecosystem

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Schematic representations of the nitrogen cycle often make it look as if the nitrogen undergoes simple chemical reactions to change from one form to another. However, while many chemical reactions do take place in the soil, the nitrogen conversions occur primarily through the action of soil organisms.

The most common form of nitrogen is ammonium ( $\text{NH}_4^+$ ), and is found in the excretions of most larger organisms. This is quickly consumed by plants, fungi and special bacteria (**nitrifying bacteria**). Their excrement contains nitrogen first in the form of nitrite ( $\text{NO}_2^-$ ), which is then consumed by other bacteria who excrete nitrogen in the form of nitrate ( $\text{NO}_3^-$ ). This is the preferred form of nitrogen for grasses and most row crops. It is not surprising then that most grassland soils are dominated by bacteria.

Most of our agricultural crops are grasses (grains, forage grasses) and grassland plants. These plants are accustomed to, and will be healthiest in, soils high in humus. Because the metabolic activity in the soil is highest during the most active growth period of plants (highest temperatures), the nitrogen will become available to plants just as it is required, so supply and demand are in perfect balance.

Soils that are low in oxygen (due to water logging, compaction, etc) contain a large number of (facultative) anaerobic bacteria (those that can exist without oxygen = **denitrifying bacteria**). These will take much of the excess nitrate ( $\text{NO}_3^-$ ) and convert it to gaseous forms of nitrogen ( $\text{N}_2$  or  $\text{N}_2\text{O}$ ) and oxygen. This supplies the **soil** with badly needed oxygen, and supplies the **nitrogen fixing bacteria** in this air-starved environment with nitrogen ( $\text{N}_2$ ). Any excess returns to the air as nitrogen gas ( $\text{N}_2\text{O}$ ).

Of course in all situations some of the nitrogen will be leached to deeper levels of the soil and into the waterways, where it feeds other organisms.

So we can see that here, too, nature creates balance. In natural systems, nitrogen is never "lost". However, with the application of chemical nitrogen fertilizers, which are either applied as nitrates, or converted to nitrates through the bacterial activity in the soil, this delicate system is disrupted. Nitrates ( $\text{NO}_3^-$ ) are anions, that is, they are not held on cation exchange sites. So anything that's not immediately taken up by plants is quickly leached out, and dissipates into the air as gas, as these fertilizers must be applied with large amounts of water to prevent salinification of the soil. **Thus the soil environment deals with the artificially created excess of nitrogen in the way the system works naturally.** Of course this leads to the pollution of our ground water and rivers, and all the health problems associated with that.

However, an excess of nitrates also creates other problems. Nitrates are salts, dehydrating their surroundings. They are also very strong oxidizers, literally burning up the organic matter in the soil <sup>(20)</sup>. These attributes not a problem in natural ecosystems where nitrates

are made available only as quickly as they can be consumed, but become a serious detriment when excess nitrates are applied.

To slow down this expensive loss of synthetic nitrogen, various forms of nitrogen are then coated, or combined with, various substances, creating so-called "slow release" fertilizers.

## **The effect of some common synthetic nitrogen fertilizers on the soil**

Supposedly these various coatings make nitrogen available at a rate plants can absorb. What all these advertisements don't tell us is that these products undergo chemical reactions in the soil, with serious "side effects" on the soil and soil life. Here are just some examples of the most common nitrogen fertilizers:

### **Ammonium sulfate** $(\text{NH}_4)_2\text{SO}_4$

#### **21-0-0 + 24% sulfur**

1. In the soil, reacts with water to produce sulfuric acid ( $\text{H}_2\text{SO}_4$ ) <sup>(1)</sup>.
2. Sulfuric acid has a pH of less than 1 <sup>(2)</sup>. It is extremely toxic and kills organisms.
3. Hydrogen ions released from the acid replace alkaline elements on the cation exchange sites, depleting the soil of nutrients <sup>(3,4)</sup>.
4. The free oxygen created in this reaction oxidizes the organic matter of the soil = causes a low level "combustion" (burning) of the organic matter. This is a purely chemical reaction which depletes the organic matter <sup>(5)</sup>.
5. In calcareous soils (soil with excess calcium) the sulfuric acid reacts with calcium carbonate ( $\text{CaCO}_3$ ) to form gypsum ( $\text{CaSO}_4$  = calcium sulfate) <sup>(6)</sup>. Gypsum is a salt and attracts water to itself and away from soil organisms and plant roots <sup>(7)</sup>. In anaerobic conditions gypsum and water form hydrogen sulfide ( $\text{H}_2\text{S}$ ), which is a toxic gas. Gypsum is banned from land fills <sup>(8)</sup>.
6. Sulfuric acid is a major component of acid rain <sup>(6)</sup>.

### **Ammonium nitrate** $\text{NH}_4\text{NO}_3$

#### **34-0-0**

1. In the soil, breaks down into ammonium ( $\text{NH}_4^+$ ) and nitrate ( $\text{NO}_3^-$ ).
2. The ammonium is consumed by plants and fungi, or by denitrifying bacteria which eventually convert it to nitrate.
3. The nitrates are consumed by soil organisms, leached, or converted to nitrogen gas and volatilized.
4. The free oxygen created through these processes oxidizes the organic matter of the soil = causes a low level "combustion" (burning) of the organic matter. This is a purely chemical reaction which depletes the organic matter <sup>(20)</sup>
5. Some biological soil scientists <sup>(8)</sup> advocate the use of small amounts of ammonium nitrate under specific circumstances even though it is prohibited for use under organic standards.

## **Urea** $\text{NH}_2\text{CONH}_2$

### **46-0-0**

1. The urea is consumed by bacteria which convert it to (excrete) anhydrous ammonia (which is a gas) and carbon dioxide ( $= 2(\text{NH}_3) + \text{CO}_2$ )<sup>(9)</sup>. Anhydrous ammonia is highly toxic and kills organisms<sup>(10)</sup>.
2. If urea is applied to the soil surface, the gases quickly dissipate. However, in the presence of high air humidity anhydrous ammonia gas vapours form. These are heavier than air and can accumulate in low lying areas<sup>(11)</sup>.
3. If urea is incorporated into the soil, the ammonia gas reacts with water ( $\text{H}_2\text{O}$ ) to produce ammonium hydroxide ( $\text{NH}_4\text{OH}$ ), which has a pH of 11.6<sup>(12)</sup>. It is highly caustic and causes severe burns. This creates a toxic zone in the immediate vicinity of the applied urea that kills seeds, seedlings and soil dwelling organisms.
4. Within a few days further chemical reactions in the soil release the ammonium ion  $\text{NH}_4^+$ , which then follows the same path as naturally occurring ammonium, with any excess nitrate created in this way leached into the environment, etc.

## **Sulfur coated urea**

### **46-0-0 + S**

1. The sulfur reacts with oxygen to form sulfur dioxide ( $\text{SO}_2$ ), which reacts with water and  $\text{NO}_2$  to form sulfuric acid (see above)<sup>(13)</sup>.
2. The sulfuric acid does what it does (see above).
3. The urea does what it does (see above) - altogether a toxic chemical soup.

## **Urea formaldehyde**

### **46-0-0 + $\text{CH}_2\text{O}$** (formaldehyde)

1. The formaldehyde dissolves in water and is leached through the soil. It is a highly toxic substance, killing all soil organisms it comes in contact with. Formaldehyde is used to preserve laboratory specimens!<sup>(14)</sup>
2. The urea does what it does (see above) - altogether a toxic chemical soup.

## **The effects of some other commonly used fertilizers on the soil**

### **Dolomite Lime** $\text{CaMg}(\text{CO}_3)_2$

1. This is not a synthetic, but a mined natural product (the only natural product in this list). Depending on the source, this contains approximately 22% calcium and 12% magnesium.
2. The ideal calcium : magnesium ratio in soils ranges from about 10:1 (general ) to 7:1 (grasses and sandy soil)<sup>(15,16)</sup>. Dolomite lime with its 2:1 calcium : magnesium ratio contains too much magnesium in proportion to calcium, especially if used routinely.

3. Excess magnesium in the soil can lead to a calcium deficiency in plants, since plants absorb calcium, magnesium and potassium largely in the ratio in which they are present in the soil.
4. In the soil excess magnesium causes a loss of soil structure (compaction), especially if the calcium base saturation falls below 60% <sup>(15)</sup>. Reduced soil air levels result in reduced root respiration and the production of toxic compounds in plants. Reduced soil air and insufficient calcium each also result in the reduction of soil microbes and the corresponding reduced breakdown of organic matter / nutrient availability to plants.
5. The effect of magnesium on the soil is well known in drilling, where magnesium is injected into the drill hole to make the drilling mud more viscous and to “tighten” the soil (it **separates** / **expands** the clay particles) <sup>(17,18)</sup>. This is also the reason why a higher percentage of magnesium is desirable in sandy soils with their loose structure.
6. Magnesium chloride is also used for dust control on roads because it creates a very hard surface <sup>(19)</sup>.

### **Potassium Chloride / Muriate of Potash KCl**

#### **0-0-60**

1. This product contains about 50% potassium and 50% chloride. In the soil the chloride combines with nitrates to form chlorine gas. This kills microbes. Applying 1 pound of potassium chloride to the soil is equivalent to applying 1 gallon of Clorox bleach. Or in other words: 2 ppm chlorine are generally thought to be sufficient to sterilize drinking water – potassium chloride application typically results in chloride levels as high as 50-200 ppm <sup>(15,20)</sup>.
2. Potassium chloride contains very high amounts of potassium, which can result in an unbalanced phosphate : potash ratio. This ratio ideally ranges from 2:1 (most soils) to 4:1 (grasses) <sup>(15)</sup>.
3. Excess potassium in the soil can lead to a calcium deficiency in plants, since plants absorb calcium, magnesium and potassium largely in the ratio in which they are present in the soil.
4. In the soil excess potassium causes a loss of structure <sup>(15)</sup>. Reduced soil air levels result in reduced root respiration and the production of toxic compounds in plants. Reduced soil air and insufficient calcium each also result in the reduction of soil microbes and the corresponding reduced breakdown of organic matter / nutrient availability to plants
5. In drilling potassium is used to “close” the soil, because it **disintegrates** the clay particles (“ages” the clay) and effectively seals the soil <sup>(21)</sup>.

### **Triple Super Phosphate**

#### **0-46-0**

1. This is produced by treating phosphate rock (apatite) with either sulfuric acid or phosphoric acid, making it extremely acidifying <sup>(22)</sup>.

2. When applied to the soil it reacts with calcium to form tri-calcium phosphate, which is water insoluble, i.e. requiring microbial action for breakdown<sup>(15)</sup>.
3. Even in a soil with healthy microbial activity only about 15 - 20% of this phosphorous is easily available to plants, considerably less in soil which does not have good microbial diversity<sup>(15,20)</sup>.
4. The production of each ton of phosphoric acid is accompanied by the production of 4½ tons of calcium sulfate, also known as phosphogypsum. This is a highly radioactive product and also contains heavy metals and other impurities. By 1989 phosphogypsum waste covered a total of 8500 acres, stacked between 3 and 60 meters high, causing serious land, air and water pollution<sup>(22,23)</sup>.
5. Depending on the production process, radioactive substances and heavy metals can be extracted into the fertilizer. The high concentration of radioactive polonium-210 in tobacco is thought to be associated with the use of acid-extracted phosphate fertilizers<sup>(24)</sup>.

These are just some examples of the potentially highly detrimental effects of some common fertilizers. It is important to know that any substance used to excess will unbalance the soil, even naturally occurring substances such as dolomite lime.

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