

# **The Use of Slow Release Nitrogen**

## **Fertilizers on the Roadside**

### ***A Literature Review***

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## 1. Introduction

Literature reviews are to a scientist what the investigative report is to a crime-beat news reporter. The investigation of the topic in question here revealed a vast wealth of information that eventually was digested as we dug deeper and deeper into the topic. With this preamble in mind, this literature review of slow release fertilizers will take many twists and turns before the full story is revealed.

The element in question, **nitrogen** (N), is essential for plant growth and animal nutrition and is the nutrient taken up in largest amount by all plants. This element's role in the environment is complex. Due to biological transformations, N exists in a variety of organic and inorganic forms. **Nitrate** ( $\text{NO}_3^-$ ) is the major inorganic form of N in most soils and is highly water soluble. Due to the fact that it is an anion, it is not attracted or retarded by the negatively charged surfaces found in soils, and therefore moves freely with percolating waters. **Ammonium** ( $\text{NH}_4^+$ ), also an inorganic form of N, is a cation and is therefore retained by the negatively charged soil surfaces. In the soil system,  $\text{NO}_3^-$  and  $\text{NH}_4^+$  are the major ionic forms involved in N flux through the complex N-cycle (Figure 1).

## 2. Fate of Nitrogen Fertilizers in the Roadside Environment

When N fertilizer is applied to the roadside, elemental N can be (1) taken up by the vegetation or microbes, (2) retained in ionic form by the soil, (3) leached to ground water, (4) carried off in stormwater runoff, (5) or lost to the atmosphere.

### 2.1 Plant Uptake

Plants only absorb  $\text{NH}_4^+$  and  $\text{NO}_3^-$ , regardless if the organic N source is organic or inorganic fertilizer. In the dynamic soil solution system,  $\text{NO}_3^-$  is more prevalent than  $\text{NH}_4^+$  because  $\text{NO}_3^-$  is not bound to the soil surface. Ammonium enters the soil solution when it is converted to  $\text{NO}_3^-$  by a microbial process called *nitrification*. In essence, these microbes convert the cation to  $\text{NO}_3^-$  as part of their metabolic process.

### 2.2 Soil Storage

Nitrogen from fertilizer can be stored in the soil-organic matrix by microbes and soil fauna. The N is said to be *immobilized* because it is converted to organic N and not available to plants until it is *mineralized* back to inorganic N. This dynamic process is controlled by heterotrophic bacteria and fungi that live off the carbon from decaying plant material and dead microbes. In newly constructed roadsides, microbes and native N (N that is in the soil prior to construction) are often lacking. Microbial activity is inhibited where the original organic layer has been removed and acid soil layers are exposed. However, once the organic matter enriched topsoil layer is restored and N fertilizer is applied, the N-cycle is set in motion. This in turn provides an available N pool that the plants can use efficiently.

## 2.3 Leaching

When N is applied to soils beyond what is required for plant uptake and maintenance of the soil microbial biomass,  $\text{NO}_3^-$  leaching and long term groundwater degradation may occur (Hallberg, 1987). Elevated levels of  $\text{NO}_3^-$  in drinking water may lead to methemaglobia in infants (NRC, 1978), the formation of carcinogenic nitrosamine in the human stomach, and hypertension (Morton, 1971). A 1990 national ground water study by the US EPA found detectable  $\text{NO}_3^-$  in 52% of the 94,600 community water systems tested, indicating widespread movement to ground water on a national scale. Much of this  $\text{NO}_3^-$  has probably migrated from improperly functioning septic systems, but agricultural contributions are also likely. Movement of excessive amounts of N and P to surface waters can result in a number of undesirable effects such as eutrophication (Keeney, 1982) and associated algal blooms and oxygen depletion. Most fresh water ecosystems are P limited, but certain oligotrophic lakes and coastal estuarine systems are limited by N (NRC, 1978). The US EPA maximum concentration limit (MCL) in water is set at 10 mg/l of  $\text{NO}_3^-$  (10 ppm) or 45 mg/l expressed as  $\text{NO}_3^-$  (Keeney, 1982).

It is well documented that  $\text{NO}_3^-$  will leach through soils; however, one cannot assume that  $\text{NO}_3^-$  will always leach when fertilizer is applied. Leaching is a complex process in soils, and is specific to topography, geology, soil type, season, precipitation, temperature, plant morphology and fertilizer applications (Keeney, 1982). The composition and amount of fertilizer applied and the time of N application can greatly affect  $\text{NO}_3^-$  losses. Generally, there are less  $\text{NO}_3^-$  losses for slowly available N fertilizers compared to quickly released fertilizers **if** they are applied at non-excessive rates (Petrovic, 1990; Turner and Hummel 1992). When N fertilizers are applied at excessive rates,  $\text{NO}_3^-$  leaching occurs (Hardt, et. al., 1993). As Keeney (1982) states, “In most cases, a close relationship existed between the amount of nitrate leached and the amount of fertilizer nitrogen used.” To minimize  $\text{NO}_3^-$  losses, fertilizer should be applied when the plants and microbes are actively absorbing N.

Precipitation, soil texture, porosity, and quality of vegetative cover strongly influence  $\text{NO}_3^-$  losses (Strong, 1995; Keeney, 1982). Turner and Hummel (1992) report in their literature review that  $\text{NO}_3^-$  leaching was most prevalent on sandy soils that received heavy irrigation. In finer textured soils,  $\text{NO}_3^-$  did not leach unless the soil was heavily irrigated or excessive N fertilizer was applied (Starrett et. al., 1995; Diez et. al., 1996). Kenna and Horst (1993) conclude in their literature review “that irrigation practices would possibly overwhelm any recommended fertilizer application rates.” Allen et. al. (1978) found that  $\text{NO}_3^-$  tended to leach more on fallow than vegetated fields which is supported by Petrovic’s (1990) findings for turfgrass. The organic matter additions to soil from the vegetation increased N immobilization, thereby decreasing  $\text{NO}_3^-$  loss. The downside to this is that when vegetation is established, the soil fauna, ie, worms and arthropods that move into the site, create macropores. It has been shown that  $\text{NO}_3^-$  may travel with gravitational water that moves quickly down these holes during heavy rainstorms or flooding (Keeney, 1982). This statement is further explained in the Groover, et. al. (1997) literature review. It was stated that “where soil  $\text{NO}_3^-$  is primarily contained within aggregated (results of mineralization, nitrification, and diffusion), water moving in macropores will carry little  $\text{NO}_3^-$  with it and subsequently  $\text{NO}_3^-$  transport will be less than predicted”.

Topography and geology play a role in  $\text{NO}_3^-$  losses. Karst topography is prevalent in western Virginia and provides a direct route of  $\text{NO}_3^-$  to the ground water. Only prudent applications of N near sinkholes should be encouraged. Horizontal layering of vastly different soils and rock strata often results from the roadside engineering processes. Little is known how these different layers affect  $\text{NO}_3^-$  loss, but Starr et. al. (1978) observed that when different materials are layered, the flow of water became complex as downward percolation “perched” above texture discontinuities.

## 2.4 Runoff

While leaching losses are generally considered to be the major environmental threat from N, runoff losses are also possible (Owens et. al., 1992). Soil erosion potential coupled with fertilizer application practices contribute to  $\text{NO}_3^-$  loss to surface water, primarily from newly applied inorganic fertilizers. Conservation tillage practices can reduce  $\text{NO}_3^-$  losses in runoff by up to 25% (Baker and Laflen, 1983). Utilization of winter cover crops such as winter rye can be effective for control of surface runoff losses (Sharpley and Smith, 1991). The roadside is especially susceptible to runoff due to steep slopes. Rough-grading, stair-stepping, straw mulch, long-fiber wood hydro-mulch and prudent N fertilizer rates would help to assure N conservation.

## 2.5 Atmospheric Losses

Fertilizer-N that is applied to the roadside can be lost to the atmosphere by either volatilization or denitrification. **Volatilization**, or the gaseous loss of ammonia ( $\text{NH}_3$ ), can occur when ammonium or urea fertilizers are applied with lime or applied on alkaline soil (Nagle et. al., 1996, Christianson et. al., 1988). Soil incorporation or light irrigation after application of urea will reduce N volatilization (Starrett, et. al., 1995). Urea applied with a hydraulic seeder may reduce volatilization; however, a tank mix of ammonium nitrate with heavy rates of lime in a hydraulic seeder may induce volatilization. When heavy rates of lime are required, the lime should be incorporated into the soil prior to seeding and fertilization. Mismanaged applications of manures and biosolids can also result in volatilization (Keeney, 1982).

Denitrification occurs when microbes reduce  $\text{NO}_3^-$  to gaseous  $\text{N}_2$  and  $\text{N}_2\text{O}$ . Fluctuating wet and cool soil conditions trigger denitrification. Denitrification can occur even when the soil is wet and cool for short periods of time; however, more N will be lost if wet conditions persist. Fertilizer losses due to denitrification can be significant. Mancino et. al. (1988) reported that 2-85% of N fertilizer can be lost from saturated silt loam soil. To avoid denitrification, increase soil aeration, avoid compaction, and maintain soil pH between 5.5 and 7.0. It is a safe assumption that  $\text{NO}_3^-$  losses from denitrification occur on the roadside, especially in drainage ditches, construction staging areas, and compacted medians.

## 3. The Role of N Fertilizers In Roadside Revegetation and Maintenance

The main goal in revegetating newly constructed roadside cuts and fills or maintaining existing roadsides is to control erosion and slope stability. Therefore, it is imperative to efficiently establish persistent vegetation. In certain roadside environments these goals are met through the establishment of mixed stands of herbaceous grasses and legumes with minimal inputs of fertilizer and other soil amendments. In other instances, particularly in the urban environment, pure stands of grasses along with ornamental plantings are required which necessitate higher levels of fertilizers, soil amendments, and management.

To met these goals, N fertilizers must be used efficiently. Ideally, N applications on the roadside should equal what the vegetation plus soil microbes/fauna require to sustain themselves. Realistically, the plant and microbes will not have access to 100% of the fertilizer-N because a portion of the N will either leach, runoff, volatilize, or denitrify. Roadside management techniques can be designed to minimize fertilizer-N loss and to increase N fertilizer efficiency. For example, rough-grading a slope will reduce N fertilizer runoff in a storm event opposed to leaving the slope smooth. The three distinct phases of roadside management: 1) development/establishment, 2) maintenance, and 3) restoration, utilize different techniques to minimize erosion and N loss as well as to encourage the development of persistent high density stands of vegetation.

### 3.1 Establishment

The **Establishment** of a stand of cool season grass, a grass mixed with legume, or a temporary stand such as German millet (*Setaria italica*) or cereal rye (*Secale cereale*) require N-fertilization because in Virginia this nutrient is in low supply or is simply unavailable in sites where the soil has been extensively disturbed. Grasses require more N during establishment than legumes (Blaser, et. al., 1980). Ideally, N should be available when the seedlings have emerged, and depending on the species, this may be 5-20 days after seeding. In all probability, N fertilizer in a quickly released form, when applied before germination, may leach because only the soil microbes are present to take up the applied N up (Geron, et. al., 1993). As the plants grow they require progressively larger amounts of N, and then N demand subsides one the plant fully matures. The ideal N fertilizer would be a slow releasing type which would delay release of N until after the seedling has germinated and then would release progressively more to plant uptake. An alternative technique would be to apply fertilizer after establishment at incrementally increasing rates as the plant grows. In current roadside management, fertilizer is applied at seeding, and refertilization does not occur for several years.

The absence of N at establishment is actually beneficial to the success of various warm season grasses in Virginia. The warm season native grasses are generally slow to germinate and do not compete well with weeds. It has been shown that fertilizing with N at planting increases undesired weed competition (Masiunas and Carpenter, 1982; Harrington, 1991; Wolf and Fiske, 1995)

### 3.2 Maintenance

The **maintenance** of legume-free cool season grasses requires periodic N fertilizer to maintain cover density which in turn controls erosion and weeds. The N application also encourages recovery from drought and traffic damage, and provides uniform turf quality (Coffman and Sawhney, 1965). Not all grass species require the same amount of N. The following grasses are ranked by their N requirements: fine fescue < tall fescue < orchardgrass < Kentucky bluegrass (Turgeon, 1991). For the maintenance of cool season grasses on the roadsides, Coffman and Sawhney (1965) recommend N fertilizer application every 4 years and McCreery and Spaugh (1977) recommend application every 4-5 years. Fall fertilization of cool season grasses is strongly recommended to promote root growth and density without encouraging excessive top growth (Watschke and Schmidt, 1992).

Warm season grasses use N more efficiently than the cool season grasses mainly because of their special C4 metabolism. Wolf and Fiske, 1995 have found that switchgrass and indiangrass require little to no N additions to remain persistent. Bermudagrass can also persist under low N availability (personal observation).

### 3.3 Renovation

Sparse vegetation along the roadside results from a combination of low soil nutrient levels, erosion, use of unadapted and short-lived species, weed competition, soil compaction, ponding, drought and even vehicular accidents. When a stand declines to the point that there is less than 50% vegetative density, the site should be **renovated** as soon as possible because as soil erosion progresses, the cost of renovation increases. Seed, lime, mulch and fertilizer are typically applied with a hydraulic seeder without surface preparation. When this mixture is applied to smooth soil surfaces, NO<sub>3</sub><sup>-</sup> losses may occur due to runoff. Nitrogen losses could be reduced while density of establishing vegetation is increased if the soil surface is scarified with a harrow prior to seeding (McIlvaine, et. al., 1980). If compaction is the culprit, ripping the site with a deep chisel plow would improve stand density as well as limit the risk of denitrification.

## 4. Nitrogen Fertilizers: An Overview

The reach of N fertilizer technology is large and is accompanied by a complex vocabulary that is associated with the different types of fertilizers that are obtainable. Over the years as N fertilizer technology has developed, words to describe N fertilizers have focused on the **release** of N. However, for this review, the fertilizers will be categorized as either **“Quickly Available”** or **“Slowly Available”** (Bruneau and Lucas, 1995; Turner and Hummel, 1992). The difference in vernacular is subtle, but provides a more accurate portrayal of fertilizer/plant relationships.

### 4.1 Quickly Available N Fertilizers - General Characteristics

Quickly available (QA) N fertilizers are also referred to in the industry as quick-release, fast-acting, readily-available, or farm-grade. The single descriptive characteristic of QA fertilizers is that they are completely soluble in water. Because of this trait, they have a high leaching risk as well as a high root/shoot burn potential. Typically, plant uptake of QA fertilizer is rapid and drops to zero as soluble-N is depleted in a relatively short time. Starr and DeRoo (1981) reported that when ammonium sulfate was applied to a mixture of Kentucky bluegrass and strong creeping red fescue, most of the plant-available N was used by the plant within 30 days after the fertilizer was applied.

The QA fertilizers are divided into **inorganic salts** and **synthetic organic** compounds. Ammonium nitrate, calcium nitrate and ammonium sulfate are examples of inorganic salt compounds. The percentage of N in these fertilizers typically ranges between 15 and 46, and they are generally less expensive than slowly available sources.

Urea and certain ureaformaldehyde products are examples of synthetic organic fertilizer compounds. Urea is manufactured from atmospheric N, is water soluble, contains 45-46% N, and has a high leaf burn potential. Urea is hydrolyzed to  $\text{NH}_4^+$  in the presence of urease, a ubiquitous enzyme. The  $\text{NH}_4^+$  is then nitrified to  $\text{NO}_3^-$ . Because these are microbial processes, urea applied to cold soils will not be available to plants, and the risks of N leaching is increased.

Some ureaformaldehyde products are completely water soluble and are listed in this QA category, even though some of their cousins are considered slowly available. For example, metholol urea fertilizer contains 50% N that is derived from short chain methyol ureas with the balance from unreacted urea. This fertilizer is water soluble and plant responses are similar to urea but without the potential foliar burn (Turner and Hummel, 1992).

## 4.2 Slowly Available N Fertilizers -General Characteristics

The fertilizer vernacular becomes confusing at this point because some slowly available fertilizers are actually a composite of quickly as well as slowly available N. The Virginia Fertilizer Law, which was derived from the Association of American Plant Food Control Official's (AAPFCO) model documents, presents the guidelines to define "slowly available plant nutrients". The entire law that pertains to slowly available N fertilizers is provided in Appendix A. In essence, if the slowly available component of the fertilizer is less than 15% of the total N, then the fertilizer can't be referred to as slowly available. The words "organic" and "natural" also cause confusion. It is often assumed that organic or natural fertilizers are slowly available fertilizers; however, this assumption is false. For example, urea, an organic fertilizer, definitely is a quickly available fertilizer.

Slowly available (SA) N fertilizers are divided into three categories: A) slowly soluble, B) slow/controlled release and C) natural organics.

### 4.2.1 Slowly Soluble - Ureaformaldehyde

#### 4.2.1.1 Description

When urea is reacted with formaldehyde, the reaction is usually not totally complete. The resulting mixture contains a combination of unreacted urea, short and long chain methylene polymers, and other trace compounds. These products are generally referred to as urea formaldehyde or UF. Table 1 provides a list of UF products that are used as fertilizers. Please note that ureaform is also referred to in the trade as UF, adding to the confusion.

These reaction products are described by cold and hot water solubility properties because they were developed in 1940's and 1950's before more advanced characterization techniques such as high pressure liquid chromatography (HPLC) were available. When UF products are tested, 1 to 1.4 grams of fertilizer are added to 250 ml of 22°C water. The fertilizer that does not dissolve in the cold water is subsequently transferred to 100°C water. **Water Insoluble Nitrogen (WIN)** is a term which denotes the percentage of N that is insoluble in both cold and hot water. The percent solubilities of N in cold and hot water are referred to in the literature as “fractions”. The following provides a description of the three fractions:

**Fraction I:** Cold Water Soluble Nitrogen (**CWSN**) - The percentage of fertilizer that dissolves in cold water is referred to as CWSN. The following components of UF dissolve in cold water: Unreacted urea, methol urea, methylene diurea (MDU) and dimethylene triurea (DMTU). Plant availability of N from this fraction is slightly slower than that of the quickly available fertilizers.

**Fraction II:** Cold Water Insoluble Nitrogen (**CWIN**) - Medium molecular weight polymers such as trimethylene tetraurea (TMTU) and tetramethylene pentaurea (TMPU) are soluble in hot but not cold water.

**Fraction III:** Hot Water Insoluble Nitrogen (**HWIN**) - The heavy, long chain polymers such as pentamethylene hexaurea are insoluble. This N release from this group of polymers, in realistic terms, is so slow that it is questionable if plants benefit from the products.

The activity index (AI) is often referred to as well as WIN when describing the slowly available characteristics of a fertilizer. The smaller number indicates that the N is more slowly available. The AI is determined by the following:  $AI = \{(CWIN - HWIN)/CWIN\} \times 100$

#### 4.2.1.2 UF Products

Urea Formaldehyde products are marketed as **granular** (ureaform, methylene urea, and MDU/DMTU compositions) or as **liquid** (UF suspensions and solutions). **Ureaform**, a “sparingly” soluble UF contains less than 15% unreacted urea with long chain polymers such as TMPU and others. As defined by AAPFCO, ureaform must contain more than 35% total N, WIN must be equal to or more than 60% of the total N, and the AI must be equal to or more than 40%. Nitroform Blue Chip™ and Powder Blue™ are commercial examples of ureaform; however, as of now the availability of these products is limited.

**Methylene ureas**, which were developed in the 1960's and 1970's, contain intermediate length polymers with 15-30% unreacted urea and can be made with various amounts of WIN. Praveen-Kumar and Brumme (1995) reported a delay period of mineralization for this group of alkylated ureas. After the delay period, mineralization occurred as rapidly as for urea. This delay period increased for the following compounds: methylurea (MU) < 1,3-dimethylurea (1,3DMU) < ethylurea (EU) < butylurea (BU) < 1,1-dimethylurea (1,1DMU), 1,3-diethylurea (1,3DEU). In the 1980's, **MDU/DMTU** granular compositions were developed. The WIN for this group is less than that of ureaform or methylene ureas. Blending ureaform, methylene urea, MDU and DMTU to create a fertilizer with various WIN provides countless fertilizer options.

The liquid products are sold as **suspensions** or **solutions**. The UF suspensions contain “microcrystalline dispersions” or commonly named “micro-prilled” suspensions of long chain UF polymers as well as unreacted urea and water-soluble UF compounds. FLUF™, Homogesol-27™, and RESI-GROW 4318™ are flowable UF suspensions which contain slowly and quickly available N sources. The **solutions** are clear and typically contain 100% water soluble UF compounds, such as methylol urea, MDU, and urea-triazone, in addition to 55% unreacted urea. They have small amount of slowly available N characteristics, but their greatest advantages are that (1) they do not burn foliage like urea, (2) N is utilized efficiently by plants, and (3) N volatilization potential is diminished (Christianson, et. al., 1988). RESI-GROW 4340 and 4341™, Formolene Plus™, Coron™ (Coron Corp., amine-modified polymethylene ureas, with 28% water soluble N), N-Sure™ (Arcadian Corp., triazone with 28% water soluble N) and Nitro-26 CRN™ are examples of clear liquid products. Even though these products have WIN, they are quickly mineralized. For example, in N-Sure™ the N was completely mineralized in 24 days (Bowman and Paul, 1991).

#### 4.2.1.3 Plant Availability

The availability of UF formulations to plants depends on dissolution process followed by microbial decomposition. The longer the polymer chain the slower the dissolution thus, slower availability. Since microbes are involved, a warm, moist, oxygen rich and moderate pH soil environment favor UF decomposition. Plants will not benefit immediately from applications of

UF fertilizers to cold or dry soils; therefore, UF products should be applied only when the soil is biologically active.

## 4.2.2 Slowly Soluble - Isobutylidene Diurea

### 4.2.2.1 Description

Urea reacted with isobutyraldehyde produces isobutylidene diurea. The compound, a white non-hygroscopic crystalline solid, is made of a single polymer in contrast to the multi-polymers that arise from the combination of urea and formaldehyde. The three particle sizes, fine (0.5-1.0 mm), coarse (0.7-2.5 mm), and chunk (2.0-3.0 mm), directly control the rate of dissolution which in turn controls the N availability characteristics. Total N of the compound must be more than 30%, and of the total N, 90% N must be WIN prior to grinding.

### 4.2.2.2 Isobutylidene Diurea Products

Isobutylidene diurea is produced by two companies as IBDU™ (Vigaro Industries) or Isoteck 31™ (Lebanon Turf Products). The Vigaro product is pure isobutylidene diurea but the Lebanon product is a combination of isobutylidene diurea and long chain methylene ureas.

### 4.2.2.3 Plant Availability

The N from isobutylidene diurea is released solely by hydrolysis, thus the release is dependent on water and pH (acid conditions increases rate of release). Because microbes have little affect on the release of this compound (unlike UF), N will release in winter. The physical standards that are used to describe UF compounds, (e.g. WIN), cannot be applied to isobutylidene diurea. Instead, the **rate of dissolution** is used. Basically, the smaller the particle, the quicker the N is available to the plant.

## 4.2.3 Slow and Controlled Release

In the 1960's encapsulated fertilizers were first developed. Since then, as the technology has expanded, remarkable coated products have been developed. These include N fertilizers coated with 1) sulfur, 2) polymer and 3) hybrids of sulfur and polymers.

### 4.2.3.1 Sulfur Coated Urea

Sulfur coated urea (SCU) technology was developed in the 1960's by the Tennessee Valley Authority (TVA). In essence, granular urea is coated with several layers of molten sulfur. Because cracks and imperfections occurred as the hot sulfur cools, a soft wax coating was added as well as flow conditioner such as diatomaceous earth. The TVA type SCU coating typically consists of 14% sulfur, 2.1% sealant, and 2.5% conditioner. The wax coating also decreases potential damage to the brittle crystalline sulfur coating that can occur with handling (Kirk, 1993).

During the manufacturing process, particle sizes (0.05 to 3.3 mm in diameter) are intentionally varied and the N content ranges between 30 and 40%. The TVA adapted the Katz Method to characterize N release from SCU. In this test, which is referred to as the Seven Day Dissolution Rate (7-day DR), the particles are submersed 24° C water. The total N that leaches into the water after 7 days is the reported test value.

Imperfections in the sulfur coating control the release of urea. The sealants, which must be degraded by microbes before release, clog the microscopic cracks and holes. As soon as microbes consume the sealant and sulfur layers, water moves into the particle through the cracks, the urea dissolves and moves out with the water. Therefore, the coating quality and thickness directly control the release of N by diffusion. Also, by blending particle size and coating thickness, the duration and rate of dissolution can provide a variety of slow release effects. Because microbes are required to degrade the coating, environmental conditions that favor microbial activity will affect the N availability.

#### 4.2.3.2 Polymer Coated Fertilizers

Technologies developed for polymer coated fertilizers have come the closest to creating a truly controlled-release fertilizer. The diffusive and semipermeable membranes that control the release of N can also be used with P and K compounds as well as for pharmaceutical chemicals. There are two types of resin coatings that are currently used: thermoset and thermoplastic resins. Osmocote™ (Agriform) is an example of thermoset resin technology that was developed in the 1960's. When the prill comes in contact with water, the “water vapor penetrates the resin coating and dissolves the water-soluble core. The dissolved nutrients then diffuse back out through the coating to the environment” (Kirk, 1993). Warm temperatures will induce accelerated release of N because the diffusion rates in water are influenced by temperature. Nutricote™ is an example of a thermoplastic coated fertilizer. The unique feature of this coating is that a “releasing agent” is built into the coating to control the diffusion of water into the core. The Scott Company has developed coated products that use copolymer blends with latex compositions. The N release is thought to occur first by diffusion of water into the prill and then by the formation of a crystalline micro-channels that allow the nutrients to flow out (Kirk, 1993). Polyon™ (Pursell Industries) utilizes a polyurathane coating that forms an ultra-thin but durable coating. The release of N is also controlled via diffusion.

Coated fertilizer's release response is difficult to characterize with the use of WIN or 7 day-dissolution rate tests. Release characteristics are described by the **duration** of release of a specific percent of N.

#### 4.2.4 Natural Organics

The N from natural organics, such as manures and waste products, is found in both slowly and readily available forms. Generally, the composted products have the higher percentage of slowly-available N. **Manures** are an agricultural by-product and contain N, P, and K as well as other essential elements such as Ca, S, B, Mg, Mn, Cu and Zn. It is not possible to

assign a general percentage of N that can be found in manures because plant nutrient levels in manures vary with animal type, age, ration and feed consumption; amount of dilution of wastewater and runoff entering the manure storage facility; and storage method and time. Table 2 provides a brief estimate of the N content of some manures. Product testing is strongly recommended prior to land applications to determine the exact nutrient content. Application rates then can be determined from the test results.

Manures that have not been composted have both, quickly and slowly available N fractions with a higher percentage of N in the quickly-available form. The quickly available fraction consists of mainly urea or uric acid. The urea in dairy and swine manure may account for 50-60% of the total N. Uric acid in poultry manure may account for 70% of the total N. The urea from manures is as susceptible to leaching and causing foliar burn as its synthetically produced counterpart.

The slowly available fraction is in the feces and is mineralized by microbes at a slow rate by a two step mineralization process. During the first year after application, the less resistant N becomes available for plant use. The decomposition rate of organic-N is greatest during this phase. During the second and third year, the resistant organic component is mineralized. Because microbes are required for the release of N from manures, more N will be available when soils are moist and warm. The carbon:nitrogen ratio influence the rate in which N is available. Generally, greater amounts of N are mineralized at lower C:N ratios. In poultry manures, the C:N ratio is approximately 7:1 or less, resulting in rapid mineralization, with most occurring in the first eight weeks after application. For dairy manures, the C:N ratio is approximately 13:1, so mineralization is slower. Swine manure mineralization rate is between that of poultry and dairy manures (Nagle et. al, 1996).

Application of manures should be made during the active growing months to avoid  $\text{NO}_3^-$  leaching. Surface applications can be made to vegetated areas, but subsurface applications should be made to bare ground to discourage runoff,  $\text{NO}_3^-$  leaching and volatilization. Application equipment to spread dry, liquid or semi-solid manures are commercially available. The box spreader or litter bodies have been developed to spread dry or semi-solid manures. Liquid manure with moisture levels greater than 87% can be applied with a liquid spreader or injector. The newer side discharge or slinger spreaders can handle a variety of manures from wet to dry (Nagle et. al., 1996).

Storage of manures is important. Once the manure is dried and processed it must be covered to exclude rain. However, if the pile can't be covered, a crust will form on the top which will shed rain. This is the least desirable storage method because manure quality can diminish over time.

**Waste products** from various industries are also a source of slowly available N. Industry produced products include bone meal, dried blood, leather tankage, fish scrap and meal. Products from agriculture include soybean, cotton, hoof and horn meal. Municipalities provide biosolids (sewage sludge) and heavy fraction wastes. The use of these products depends on local availability, acceptance and experience. Because biosolid quantity and availability is dependable, this product has become the waste product of choice for agricultural and soil reclamation use.

Biosolids are the solid residue material that remain after treatment plants purify wastewater from homes, business and industries. In some regions, runoff from roads, lawns and fields is also processed. Biosolids are composed of **inorganic** constituents such as macro and micro-nutrients and non-nutrient trace elements, **organic** compounds, and **microbes** (Nagle et. al., 1996).

Figure 2 provides a schematic view of the wastewater treatment process used to produce biosolids. In actuality, the water and solids that are removed from the wastewater are simultaneously treated by different but intermingled processes. As the wastewater enters the plant, a screen removes large objects and a settling chamber removes grit. The wastewater then travels through a sedimentation basin where much of the solid matter is separated from the liquid. The biosolids at this stage are rich in microbes that are used to digest the organic matter in the entire system. The biosolids that are collected from the primary, secondary and advanced water treatment process are referred to as “activated” because the microbes are present. These solids are combined, thickened, and “stabilized”. The stabilization process destroys most pathogens, reduces any offensive odor and readies the biosolids for dewatering. Once dewatered, the biosolids are ready for use.

The biosolid can be formulated several ways to provide easier handling. “Cake” biosolid has a solid content of 18-25% and can be applied with a spreader similar to a dry manure spreader. Liquid biosolid contains 2-5% solids and is applied by irrigation or injection. Biosolids can be composted with wood chips or sawdust and applied with a mulch spreader. Pelletized composted biosolids are also commercially available, ie., Terrene and Milorganite™.

The N content of biosolids varies and should be tested prior to use. The *Chesapeake Bay Region Nutrient Management Training Manual* (Nagle et. al., 1996) provides a detailed description for testing and estimating application rates. Generally, the N and P content are similar to those in animal manures, but K is usually low. Similarly to manures, a portion of the inorganic N is quickly available, but unlike manures, the N is in the form of  $\text{NH}_4^+$  and  $\text{NO}_3^-$ . The C:N ratio directly influences the mineralization of N from the organic N fraction. For composted biosolids, 5-10% of the organic N will mineralize; however, 20-30% of the organic N in stabilized biosolids will mineralize. Typically, the percent N for activated and stabilized biosolids is 4.9% and 2.9%, respectively. Because of the quickly-available N fraction in biosolids, biosolids should be applied during the growing months to avoid  $\text{NO}_3^-$  leaching. Composted biosolids will have a greater percent of organic N and is considered a better slowly available source of N than other biosolid forms.

Natural organics are not as easy to manage as other N fertilizer sources because they often do not come bagged, require specific storage facilities, and require considerable testing prior to use. However, the benefits from the additional nutrients and organic compounds that improve the general edaphic environment generally outweigh the drawbacks. Organic matter applications to mined land restoration promotes long term persistent vegetative cover. However, poor management of natural organics can result in  $\text{NO}_3^-$  pollution just as easily as with urea or ammonium nitrate fertilizers.

#### 4.2.5 Nitrification and Urease Inhibitors

Nitrification and urease inhibitors are commercially available and have been marketed as a tool to release N slowly into the soil. Generally, the **nitrification inhibitors** prevent the nitrification of  $\text{NH}_4^+$  to  $\text{NO}_3^-$ . N-Serve™ from Dow Elanco (nitrapyrin) will prevent this biological process from occurring, but due to the volatility of the chemical, its use on turfgrass has been questioned (Turner and Hummel, 1992). The compound dicyandiamide (DCD) is another inhibitor that contains 66% N. When this compound was combined with urea, Mosdell et. al. (1986) found that even though nitrification inhibition occurred, the short duration of the effect of urea plus 10% DCD did not warrant the use of the product. **Urease inhibitors** inhibit urease activity, the enzyme that drives the hydrolysis of urea to  $\text{NO}_3^-$ . These compounds have been shown to reduce volatilization of ammonia from urea, but the use of these compounds is not realistic for use on a large scale (Turner and Hummel, 1992).

#### 4.2.6 Gel-Forming Hydrophillic Polymers

The hydrophillic polymer technology has expanded in the past few years. The basic concept is to incorporate nutrients into a polymer gel complex. When applied to the soil the release of N is slow and steady. Leaching of  $\text{NO}_3^-$  from soil columns has been shown to decrease by 45% if urea ammonium nitrate was combined with a polymer as compared to non-modified fertilizer (Mikkelsen et. al., 1993). The amount of N that accumulated in tall fescue dramatically increased with the use of the polymer as compared to fertilizer alone. The potential use of this technology in the future looks plausible mainly because the products are relatively inexpensive as compared to some other slowly available products (Mikkelsen, 1994).

### 5. Slowly Available N Fertilizers: The Roadside Connection

Efficient use of N takes on a new meaning when applied to the roadside environment, primarily because cost is the major force in determining how much, how often, and what type of fertilizers are used. In Virginia, where the one-shot-seeding technique prevails, enough quickly available N fertilizer is applied at establishment to hopefully produce persistent vegetation that will control erosion. The reality is that the roadside managers often have to reseed and fertilize within a year after roadside construction has been completed because the vegetative cover is not adequate to control erosion. This decline of the newly seeded roadside can be attributed to many factors; however, one of the easiest to correct is low N fertility. Increasing the amount of quickly available fertilizer applied at seeding does not “fix” the problem; however, a follow-up N application in the fall following seeding will increase stand density (Blaser, et. al., 1980; Watschke and Schmidt, 1992).

Seeking an alternative management technique to that which was just described may be beneficial. Perhaps the use of slowly available N fertilizers could provide a added management tool. In theory, slowly available fertilizers applied at establishment could eliminate the need for

the two phase fertilization technique that is presently. In theory, the delay release feature, which several slowly available fertilizers offer, could promote better seedling development and reduce the potential of NO<sub>3</sub><sup>-</sup> loss. In theory, an application of slowly available fertilizer at establishment could release N at an adequate rate that would support growth for at least 4 years. In theory, a maintenance application of slowly available N could be made to satisfy stand N requirements for five or more years.

Finding the connections between available research and the roadside environment to substantiate these concepts requires some ingenuity because the slowly available fertilizer research relating directly to the roadside is limited. However, an examination of (1) roadside research pertaining to the use of quickly available fertilizer and of (2) fine turf research pertaining to the use of slowly available fertilizers provides supplementary information.

### 5.1 Roadside Foundation Research - Quickly Available N Fertilizer

The original research on the use of quickly available fertilizer on the roadside was completed in the late 1970's in Virginia, and the current VDOT fertilizer specifications are based on that work. The following recommendations were made by Dr. Roy Blaser and his group of researchers and subsequently expanded upon by others (Blaser et. al., 1980; Green et. al., 1973; McIlvaine et. al., 1980; Wright et. al., 1978):

*A. Fertilizer recommendation for the **establishment** of vegetation with the one-shot seeding technique:*

- When establishing a persistent vegetation cover of grass and legume, apply 112 kg/ha of quickly soluble N fertilizer.
- When establishing tall fescue grass on bare ground, apply 112 kg/ha of quickly soluble N fertilizer and 336 kg/ha of urea formaldehyde or isobutydiene diurea.
- When establishing temporary covers (annual rye, cereal rye, German millet or weeping lovegrass), apply 56 kg/ha quickly soluble N fertilizer.
- When overseeding a legume into an established stand of tall fescue, apply 56 kg/ha quickly soluble N fertilizer.
- Warm season grasses, when established in the spring, performed better when fertilized with less than 34 kg/ha of N. A reapplication of fertilizer 4-5 years after initial seeding in the spring was recommended (McCreery and Spaugh, 1977).

*B. Fertilizer recommendation for the **establishment** of vegetation with the multi-step seeding technique:*

- Dr. Blaser introduced the **concept** of multi-step seeding and fertilization because the results of establishment were superior to the “one-shot seeding” approach (Blaser and Woodruff, 1968). The technique was especially successful when seeding in the difficult summer and winter months and on steep slopes.
- In the **summer**, a temporary stand of German millet or weeping lovegrass would be established with 56 kg/ha quickly available N fertilizer . In the fall, grass with or without a legume would be sown with 34-56 kg/ha quickly soluble N fertilizer.

- In the **winter**, a stand of cereal rye and hard fescue or tall fescue would be established with 56 kg/ha quickly soluble N fertilizer. In the fall, grass with or without a legume would be sown with 34-56 kg/ha quickly soluble N fertilizer.
- When sowing on difficult to revegetate sites such as **steep slopes**, a split application (not the one-shot-seeding technique), of N fertilizer could be beneficial. At the time of seeding, 56-78 kg/ha quickly soluble N fertilizer is recommended. Then a fall application of 34-56 kg/ha quickly soluble N fertilizer (Blaser et. al., 1980, Wright et. al., 1978) is applied.

*C. Fertilizer recommendation for the **maintenance** of vegetation:*

- An application of 56 kg/ha of quickly soluble N fertilizer to tall fescue stands is recommended when the stand starts to decline, every 2-4 years (McIlvaine, et. al., 1980).

*D. Fertilizer recommendation for the **renovation** of vegetation:*

- When the vegetation density is not less than 50-60%, application of 56 kg/ha of quickly soluble N fertilizer to tall fescue stands is recommended.
- When the stand density is less than 50%, use the establishment rate of quickly available N fertilizer with a half rate of seed (McIlvaine et. al., 1980; Wakefield and Sawyer, 1982).

## 5.2 Fine Turf and Roadside Research - Slowly Available N Fertilizers

Conceptually, slowly available fertilizers could be beneficial to the roadside vegetation. However, the supporting research is scarce. The following concepts are outlined and the supporting research is presented.

**Concept 1:** *“Slowly available fertilizers applied at establishment could eliminate the need for the two phase fertilization technique.”*

Some slowly available products that are applied at the time of seeding can provide ample N to support establishment, and to provide adequate N to produce quality vegetation for one year. The products such as the long chain ureaformaldehydes, coarse isobutylidene diurea, SCU, polymer coated urea, and natural organic products fit this criteria. Blaser et. al. (1980) recommended the application of 336 kg/ha of ureaform or isobutylidene diurea at the time of seeding to provide slowly available N to developing tall fescue seedlings. Organic N from the heavy fraction of municipal waste (MHF) that was incorporated into the soil prior to seeding tall and fine fescues, has been shown to provide ample N to support the growth the tall fescue and fine fescue four years after seeding (Booze-Daniels and Schmidt, 1994). Conclusive research on roadside applications of SCU, polymer coated urea and natural organics is yet to be done.

**Concept 2:** *“The delay release feature could promote better seedling development and reduce the potential of  $NO_3^-$  loss”.*

The delay in release is best documented in isobutylidene diurea, polymer coated urea, SCU, and ureaform (Brown et. al., 1982; Kirk, 1993; Landschoot and Waddington, 1987; Zhang et. al., 1994). The delay release of N form polymer coated urea is the most precise, is unaffected

by microbes, and independent from temperature to a certain degree. Isobutylidene diurea delay is related to moisture and particle size (Hughes, 1976). If the fertilizer is applied at the time of seeding and the N is released when the seedlings emerge (5-10 days for tall fescue) the N would be available for the growing seedling.

**Theory 3:** *“An application of slowly available fertilizer at establishment could release N at an adequate rate that would support growth for at least 4 years”.*

At this time the number of slowly available N fertilizers that fit this concept are few. Specific formulations of natural organics, long chain UF, isobutylidene diurea, SCU, and polymer coated urea can provide N for two years after application; however, with the exception of the natural organics, it is not known if the N rates are sufficient to maintain roadside vegetation for 4 years. Hummel and Waddington (1984) reported that the TVA SCU-11 (36% N, 11% 7-d dissolution rate) released N three years after application, but did not mention the impact on turf growth. Natural organics such as composted biosolids, manures, and MHF would provide at least a 5 year release of N (Booze-Daniels and Schmidt, 1994; Nagle et. al., 1996). When isobutylidene diurea was applied at 78 kg N/ha with ammonium nitrate (at the same rate), the three year roadside response of tall fescue was better than when only ammonium nitrate was applied (Schmidt and Nabati, 1991; Nabati and Schmidt, 1992; Schmidt and Rucker, 1988).

The UF, SCU and polymer coated ureas that last 2-3 years are either expensive or are not presently commercially available. However, the natural organic N-fertilizers are available, are comparatively inexpensive, and promote long term persistent vegetation for at least 4 years.

**Theory 4:** *“A maintenance application of slowly available N could be made to satisfy vegetative N requirement for five or more years.”.*

As previously discussed, long term N release from fertilizers is possible, but as time progresses, the rate and amount of N released diminishes. This is especially true with UF, isobutylidene diurea, and the coated ureas. None of these product will provide an adequate pool of N for five or more years. The natural organic N-fertilizers (biosolids, manures, and municipal solid waste) will provide adequate pool of N for five or more years. Some of these products can be applied over established vegetation, as required for maintenance. If site renovation is required, the natural organics are especially effective in stand establishment.

### 5.3 Management Concerns with N Fertilizer Sources

Many of these slowly available fertilizers unlock a whole new realm of management opportunities by allowing greater control of N timing for improved vegetation performance, reducing  $\text{NO}_3^-$  losses, and increasing N efficiency. These products are unconventional and sometimes daunting for certain managers because they “behave” differently than quickly released N. Some products have delay features, are temperature dependent, can't be applied with a paddle type hydraulic seeder, and should not be applied late in the fall because N will be released in the winter when N leaching is more likely to occur. These “behavior” idiosyncracies are similar to what managers experience with pesticides. Once the products are understood, their use becomes easy to specify.

#### 5.3.1 Ureaformaldehyde Products

NOTE: The most important characteristic of this group of products is that the release of N is biologically dependent on microbes. Therefore, warm temperatures will favor N release. The second unique characteristic is that a single fertilizer product, for example methylene urea, is composed of an assortment of different UF compounds as well as unreacted urea. The third characteristic is that WIN is used to describe the percent of slowly available N in the product.

Not all UF products are slowly available and should be acknowledged as such on the fertilizer label. When WIN is indicated on the label, this number should be divided by the % total N and then multiplied by 100 to calculate the percent of total N that is WIN (slowly available) (Appendix A). Please note that urea is marketed as a “organic N source”. Because UF products contain certain proportions of unreacted urea, these products can also be marketed as “organic N source”. Please do not assume that all organic N products are slowrelease N products.

ROADSIDE USE: The long chain polymers in Ureaform (UF) provide a long term N source. Landschoot and Waddington (1987) reported that the residual of UF was detected three years after treatment. However, the rate has to be relatively high to provide an adequate continual source of N which in turn induces a growth response for fine turf (Ledebor and Skogley, 1973). McIlvaine et. al. (1980) applied 112 kg/ha of ureaform, SCU or ammonium nitrate to tall fescue on the roadside in the spring. They observed little grass growth or increased density with the ureaform at this rate. This lack of response from ureaform is common in the general turf literature. However, long term (3-4 years) roadside research on ureaform may indicate that the use of ureaform is beneficial. Combining a low WIN, such as methylene urea or urea with a high WIN UF product may provide ample N for establishment and subsequent growth demands.

APPLICATION REQUIREMENTS: The microprill suspension and soluble and granular UF products can be applied with a hydraulic seeder. The granular formulations can be applied with blower, spin or drop spreaders. Application could be made anytime during the year except when the ground is frozen. If increased vegetation density is desired, applications of high WIN UF should be made in late spring or summer so that release of N can occur primarily in the fall. The industry uses the general rule of 2/3 release the first year and 1/3 release by the second year for UF product with high WIN such as ureaform.

### 5.3.2 Isobutylidene diurea

NOTE: The unique characteristic of this product is that release is not dependent on temperature or microbes; however, it is dependent on water. Therefore, release occurs in the winter as well as the summer. The implication is that cool season grasses can be dosed with a continual release of N in the fall when the roots are still growing but the soil is too cool for optimum microbial functions. The second characteristic of importance is that release rate is

controlled by particle size. Coarse size provides long term release of N opposed to small particle size.

**ROADSIDE USE:** This product would be ideal for seeding because of its inherent delay of N release. After the seedlings germinate, the subsequent release of N would provide short and long term N if particle size is varied. Also, the coarse particle sizes combined with an application of quickly available fertilizer or even short chain UF could serve as a fall maintenance fertilizer. The more quickly available N would increase vegetative density while isobutylidene diurea would supply long-term N.

Nabati and Schmidt (1992), have shown that when ammonium nitrate plus IBDU™ (157 kg/ha from each fertilizer) was applied to tall fescue on the roadside, percent density improved when compared to ammonium nitrate alone (78.4 kg/ha). In another roadside study, IBDU™ applied at the rate of 90 kg/ha of N promoted acceptable tall fescue density (Schmidt and Nabati, 1991). Also, when IBDU™ and urea were blended and applied at 134 kg/ha of N (1:1), percent density of tall fescue improved.

**APPLICATION REQUIREMENTS:** The granular product can be applied with a blower, hydraulic seeder, or spin- or drop-type spreader.

### 5.3.3 Sulfur and Polymer Coated Urea

**NOTE:** The distinguishing characteristic of this group of fertilizers is that urea, a quickly available N source, is coated, thereby physically releasing urea at a controlled rate. The coatings of SCU control the rate and duration of release. The coating of the polymer coated urea controls the rate and duration as well as initial delay patterns. SCU requires microbes for the release of N; thus, this product is temperature dependent and release is minimal in the winter. The polycoated ureas are less temperature and microbe dependent than SCU. Seven-day dissolution rates are used to characterize this group of fertilizers. The smaller the number, the slower the release rate. The polycoated ureas are typically characterized by the coating thickness. The thicker the coating, the longer duration of release.

**ROADSIDE USE:** The SCU and polymer coated ureas that are formulated for a long duration of release would benefit the roadside vegetation. Nabati and Schmidt (1992) reported that the density of tall fescue was adequate when fall fertilized with both SCU and Escote 270™ (polymer coated urea). They also found that by adding urea to SCU or Escote 270™, less coated fertilizer was required to provide the same result; thus, additions of urea to coated fertilizers could reduce cost, but still provide the benefits of the slowly available products.

**APPLICATION REQUIREMENTS:** The SCU and polymer coated ureas can be applied with a drop, blower or spinner spreader, as long as the spreader does not damage the coating. Once the coating is compromised, the fertilizer behaves the same as uncoated urea. SCU should not be applied with a hydraulic seeder. Some thick walled polymer coated urea may be applied with this type of seeder, but the product should be tested prior to use (personal communication, John Detrick, Pursell Industries, Inc).

#### 5.3.4 Natural Organics

NOTES: Natural organic fertilizers offer “more for less” as compared to most N fertilizers. Not only do they provide both quickly and slowly available N, they also have the added bonus of organic matter, micronutrients as well as antioxidants. As previously discussed, the addition of organic matter to a newly constructed roadside system that is devoid of this material can improve soil structure and water holding capacity. There is no question as to the advantage of these products to the establishment and long term persistence of roadside vegetation.

Natural organics are available in a highly processed form such as Milorganite™, a composted form such as biosolid or poultry manure, or an unprocessed form such as semi-liquid poultry litter or swine manure. The composted and processed materials generally contain less N, have less odor, are easier to handle, and generally are more expensive than the raw materials. The overall cost of the natural organics are usually less expensive than the other slowly available N fertilizers and even less expensive than some quickly available N fertilizers.

ROADSIDE USE: Because biosolids are abundant, this natural organic fertilizer is a logical choice for roadside use. The incorporation of composted or non-composted biosolids into the seedbed prior to seeding would provide a slow release of N, macro- and micro-nutrients, organics and better moisture retention for the developing seedlings (Walker et. al., 1996). During the first year, 10% of the N from some composted biosolid would be potentially available for plant use, 5% the second year and 3% the third year. For example, if 44,800 kg of biosolids was applied to hectare of roadside and the compost contains 3% N, then the compost has 1,344 kg/ha of total N. If the potentially available N (PAN) of the compost is 10% for the first year, then 134 kg/ha of N will be released the first year, 67 kg/ha the second year and 40 kg/ha the third year. If biosolids are used at the time of seeding, the site most likely will not require a maintenance application of N until 5 or more years after establishment.

Composted yardwaste, also an expanding source of organic matter, improves the edaphic environment; however, the N concentration of the yardwaste is generally too low to be used as a significant N fertilizer. However, yardwaste (either surface-applied or incorporated into the soil) that is supplemented with quickly available N fertilizer can provide a superb seeding bed, especially for roadside areas which are difficult to establish (Booze-Daniels and Schmidt, 1996). The heavy fraction from municipal waste (screened household garbage minus the metals, glass and plastics), when applied at establishment, will provide enough N in a slowly available form to maintain a stand of tall fescue for at least 4 years (Booze-Daniels and Schmidt, 1994).

The natural organic composts and some raw fertilizers are ideal for use on harsh sites that would benefit from additions of organic matter. The wildflower plantings in medians, seeding attempts on poorly buffered acidic soils, and high-cost plantings such as shrubs and trees would respond favorably to the natural organic products. In addition to the benefit from the N, organic matter, and micro-nutrients, improved seeding success as well as drought tolerance have been attributed to natural organics (Schmidt 1992).

APPLICATION REQUIREMENTS: Non-processed natural organic fertilizers can be applied in liquid, semi-solid or solid formulation. Spreaders have been developed to aid in application. Surface application followed by light tillage is best, but some organics can be left on the surface prior to seeding.

The composted and processed products such as Milorganite™, Sustain™ or Hydropost™ can be applied with any type of spreader, including hydraulic seeders (Haynes, 1997).

### 5.3.5 Gel-Forming Hydrophillic Polymers

NOTE: This innovative type of slowly available fertilizer is very new and has not been tested on roadsides, but is reported to have potential. The fertilizer saturated gels would be easy to apply with any type of non-hydraulic spreader. A hydraulic seeder could possibly be used as long as the gels would not clog the plumbing. More research in this area is suggested.

## 6. Conclusion

As this investigation unfolds it is clear that establishment of grasses without legumes requires N fertilization not only at establishment but also over time to avoid stand decline. If quickly available sources of N fertilizer are used, refertilization is required every 4 to 5 years. Several months after the N is applied, the N fertilizer no longer exists in its original form. It has either been fixed in the living and dead organic matter in the soil system, held within the plant, flushed from the soil with water, or has volatilized into the atmosphere. At this point, cycling of N through the dynamic soil/plant system is the sole source of N for the grasses. Eventually, less and less N will be available for grass uptake. When this downward spiral reaches a certain point, more N-fertilizer has to be applied to prevent a decline in the stand.

The literature notes that some long chain ureaformaldehydes, coarse isobutylidene diurea, specific formulations of sulfur and polymer coated urea, and some natural organic N fertilizers can release N over one to four years. These products provide N long after quickly available N fertilizers have solubilized. With this extended release of N into the plant/soil system the cycling of N is also extended. The downward spiral to the point of stand decline, hypothetically, can be stretched to eight years after initial fertilization.

To the roadside manager, a fertilizer program for non-legume grass stands based on an 8 year rotation would sound great. However, the manager will have to balance the benefits with the cost of slowly available N fertilizer. In the end, the manager may decide that the use of a legume would be a more plausible alternative.

The concern to reduce NO<sub>3</sub><sup>-</sup> contamination of the ground water, surface water, and the Chesapeake Bay also enters into the question of whether or not to use slowly available N

fertilizers. The answer to this question is based on management practices. The quickly available N fertilizers, if used *prudently*, will most likely not contaminate water. On the other hand, misapplied slowly available N fertilizers can be a threat to water supplies. However, carefully selected and applied slowly available N fertilizers logically can reduce NO<sub>3</sub><sup>-</sup> leaching, especially when used around environmentally sensitive areas, such as sink holes, steep slopes, stream banks, etc.

Lastly, the use of natural organic fertilizers, i.e., biosolids, manures or other waste products, on the roadsides is strongly encouraged. Even if legumes are used, the use of organic fertilizers can increase stand uniformity. This in turn will reduce erosion and protect water quality. The use of natural organics on the roadside is a winning solution for the waste utilization industry and VDOT. As the cliché goes, “one person’s garbage is another person’s treasure”.

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Table 1. A list of urea formaldehyde fertilizer products and general attributes. Urea is included as a comparison.

Fertilizer	Percent N		Formulation	Examples
	Total N	% WIN of Total		
Ureaform	35-38	65-71	solid	Powder Blue, Meth-Ex 38
UF Suspension	18	4	flowable solids	FLUF, Resi-grow, Hydro Seeding Special
Methylene Urea	39-40	14-36	solid	ProTurf, Scots HD, ProGrow, Nutralene
MDU plus DMTU	40-42	10	solid	Scots Triaform
MDU	26	0	liquid	Nitro 26
Methylol urea	26-30	0	liquid	CoRon, GP 4340, Formalene
Urea Trizone	28	0	liquid	N-Sure, Trisert
Urea	46	0	liquid or granular	

Table 2. Average Nutrient Values for Various Manures. Values presented in lbs/1000 gallons. All other values in lbs/ton. The table is a compilation of average values for 1090 manure samples (Nagle et. al., 1996).

<u>Manure Type</u>	<u>Total N</u>	<u>NH<sub>4</sub><sup>+</sup></u>	<u>P<sub>2</sub>O<sub>5</sub></u>	<u>K<sub>2</sub>O</u>	<u>Ca</u>	<u>Mg</u>	<u>% Moisture</u>
Liquid Dairy	22.61	9.57	12.07	18.92	10.90	4.55	94.30
Dry Broiler Litter	62.58	11.75	62.12	28.57	40.97	8.44	28.43
Dry Turkey Litter	61.75	15.18	63.68	24.36	43.11	7.02	34.72
Layer or Breeder	36.46	8.98	65.06	24.22	123.38	7.67	43.28
Liquid Poultry	51.08	32.95	41.01	30.53	40.05	5.19	93.49
Semi-Solid Dairy	10.54	3.16	6.12	8.67	6.90	2.50	82.56
Semi-Solid Beef	12.79	2.57	6.67	11.30	7.43	2.69	73.08
Swine Lagoon	10.04	5.34	5.68	5.72	2.49	0.89	99.01
Mixed Swine	1.13	26.93	29.75	18.18	16.44	4.86	94.97

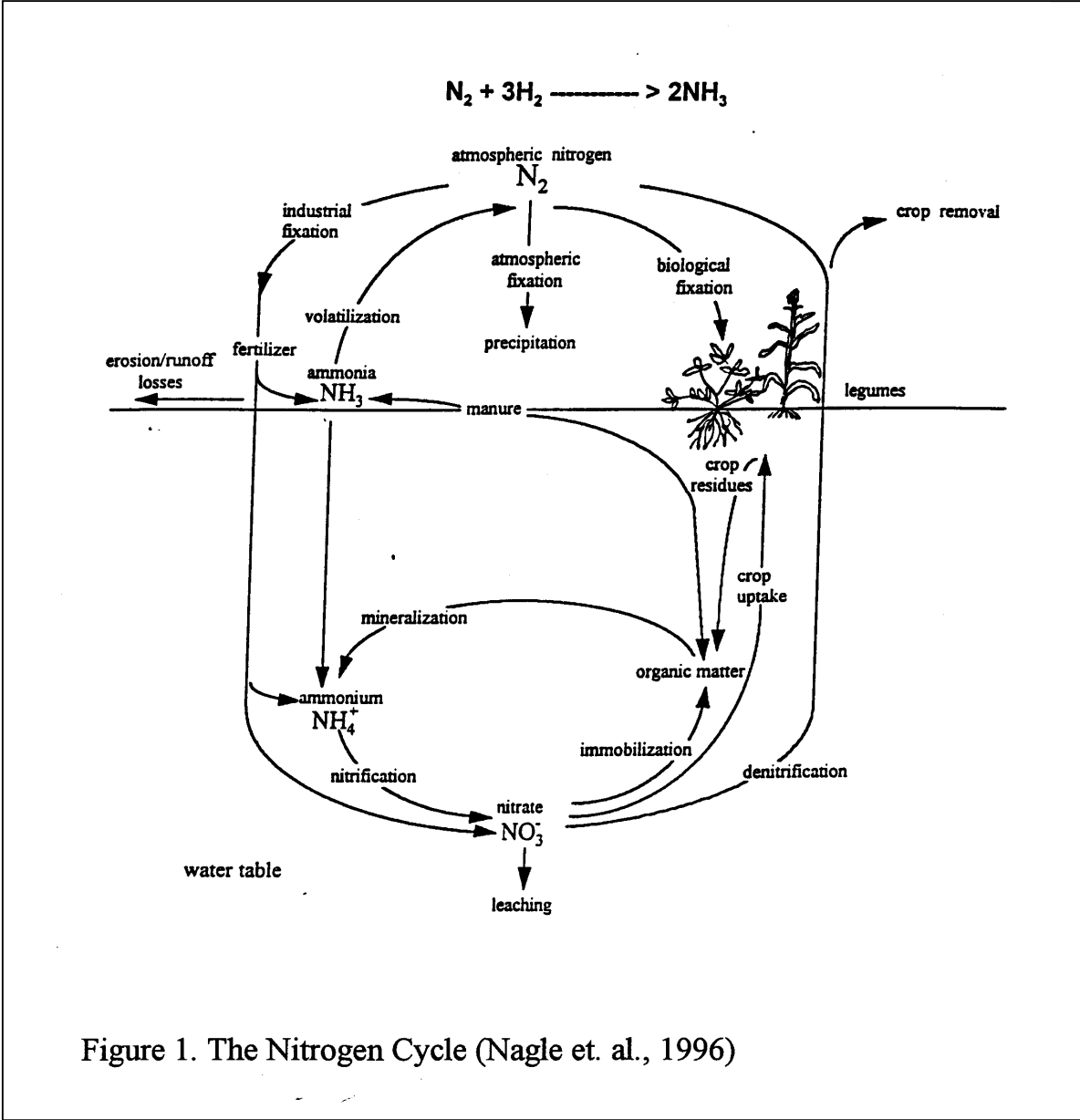


Figure 1. The Nitrogen Cycle (Nagle et. al., 1996)

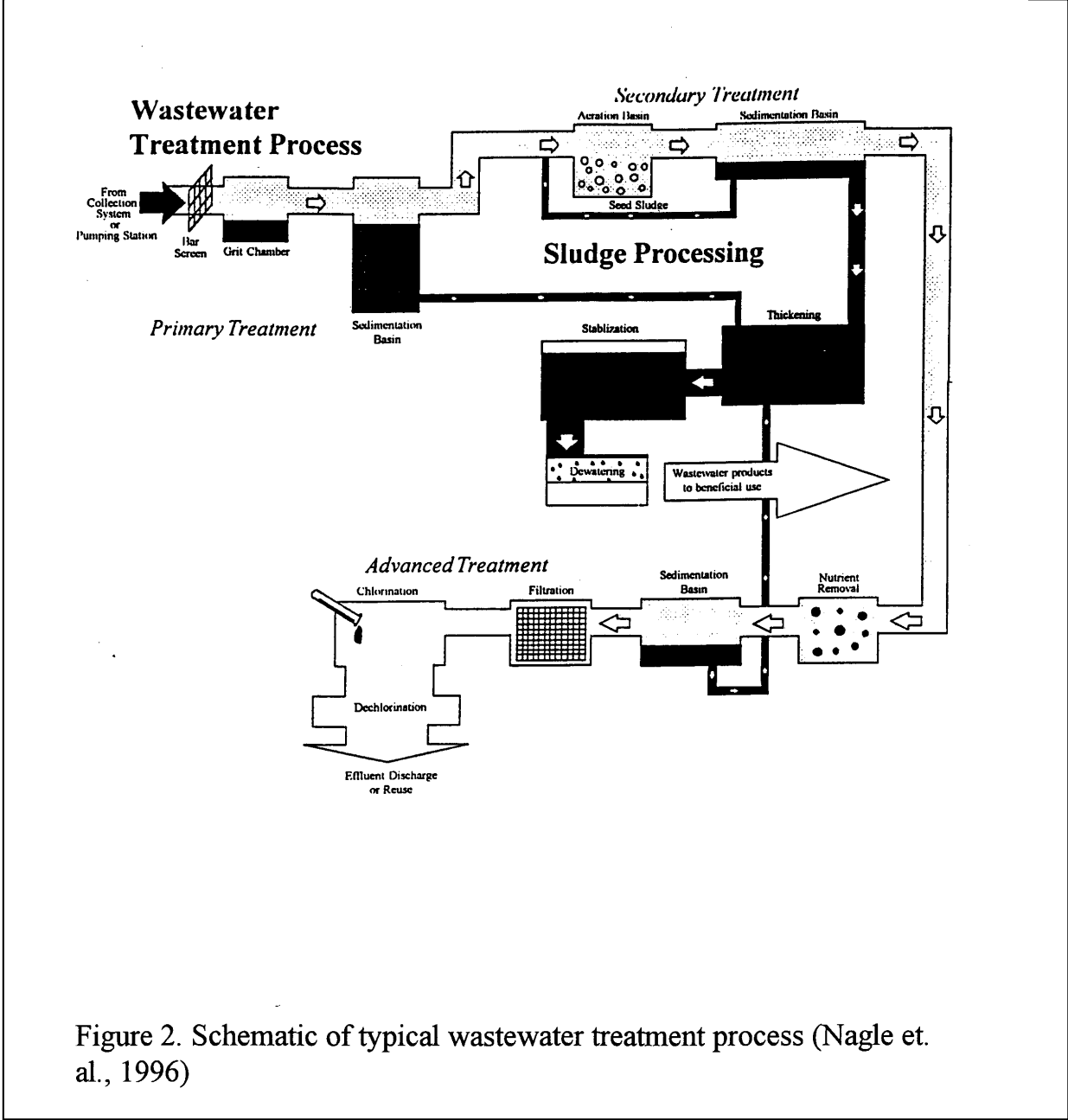


Figure 2. Schematic of typical wastewater treatment process (Nagle et al., 1996)

## Appendix A.

Rules and Regulations for the enforcement of the Virginia Fertilizer Law, Va. Dept. Of Ag. and Consumer Services, Division of Product and Industry Regulation, 1100 Bank St., Richmond, Va 23219, pages 5-9.

### Slowly Available Plant Nutrients

1. No fertilizer label shall bear a statement that connotes or implied the presence of a slowly available plant nutrient unless the nutrient or nutrients are identified.
2. When a fertilizer label implies or connoted that the nitrogen is slowly available through the use of “organic”, “organic nitrogen”, “ureaform”, “long-lasting” or similar terms, the guaranteed analysis must indicate the percentage of water insoluble [or slowly available] nitrogen in the material.
3. If a label stated the amount of organic nitrogen present in a phrase, such as “25% of the nitrogen from ureaformaldehyde (ureaform), “ then the water insoluble nitrogen guarantee must be not less than 60% of the nitrogen so designated.

Example:       10-6-4 Rose Food  
                          25% of Nitrogen is Organic

$10 \text{ (total N)} \times .25 \text{ (%N claimed or Organic)} \times .60 \text{ (Average insolubility in H}_2\text{O) of organic nitrogen sources} = 1.5\% \text{ WIN}$

4. When the water insoluble [or slowly available] nitrogen is less than 15% of the total nitrogen, the label shall bear no references to any designations such as stated in subsection B. paragraph 2. of these regulations.
5. The term “Coated-slow release fertilizer”, or “Coated-slow release” shall be accepted as descriptive of products.
6. Further, the terms and phrases in subparagraphs 2. and 5. of this regulation shall be allowed for any products that can show a testing program substantiating the claim. (Testing under the guidance of experiment station personnel, or a recognized reputable reseracher, etc.)
7. Association of Official Analytical Chemist (AOAC) Method 2,047 shall be used initially to substantiate the fact that “Coated-slow release” materials are present. The determination need only be modified by the elimination of sample grinding during preparation.

## Appendix B. Examples of general fertilizer calculations.

### I. Calculating WIN

For UF based fertilizers, the portion of nitrogen (N) that is slowly available is listed on the fertilizer bag as Water Insoluble Nitrogen (WIN). (If the WIN is not stated, assume that all the fertilizer is quickly available unless the fertilizer label indicates the presence of sulfur coated urea.) For example, a 20-10-10 fertilizer with 5% WIN has 5/20 or 1/4 of the N in the slowly available form.

To find the %N that is WIN:

$$\frac{\% \text{WIN} \times 100}{\% \text{ Total}} = \% \text{ total N that is WIN or slowly available}$$

Thus:

For a fertilizer that has the guaranteed analysis of 20-10-10 with 5% WIN,

$$\frac{5}{20} \times 100 = 25\% \text{ of the total N is WIN.}$$

### II. Calculating how much fertilizer of different formulations to apply to 1 acre.

The following calculation can be used to determine how much fertilizer should be applied to 1 acre:

$$\frac{\text{Desired lbs of N per 1 acre}}{\% \text{ N in fertilizer}} \times 100 = \text{lbs of fertilizer needed per acre}$$

Example 1

If one wants to apply 90 lb of N per acre using 15-30-15, a quickly available fertilizer:

$$\frac{90}{15} \times 100 = 600 \text{ lbs per acre of 15-30-15 is required to provide 90 lb/A of nitrogen.}$$

Example 2

If one wants to apply 90 lb of N per acre using 22-0-16, with 7.3 WIN, a slowly available fertilizer:

$$\frac{90}{22} \times 100 = 409 \text{ lbs per acre of 22-0-16 is required to provide 90 lbs/A of nitrogen.}$$

BUT, of the 90 lbs of N that is applied to the acre, 30 lbs will be in a slowly available form.

To arrive at this WIN calculation:  $(7.3 \div 22) \times 100 = 33\%$ , then  $.33 \times 90 = 30$  lbs. The 30 lbs of slowly available N is used by the turf over a longer span of time than the 60 lbs of quickly available N.