Manure Mineralization in Soil

The mineralization of manure is governed by the biological, chemical, and physical properties of soil and is a function of the organic manure, soil moisture, and soil temperature. Manure mineralization is a process where microbes digest and reduce the organic portion of the manure to inorganic materials. Inorganic materials released during this process are the essential plant nutrients (N, P, potassium), macronutrients and micronutrients, salts, and heavy metals.

Soil moisture, temperature, and aeration regulate soil microbial activity, and thus are factors that influence the rate of manure mineralization. Soils that are warm, moist, and well aerated have the highest potential rate of organic manure mineralization. Lower potential rates should be expected when soils are dry, cold, or saturated with water.

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Microbial activity

Average annual soil surface temperature and seasonal temperature variations have a significant impact on the duration and rate of soil microbial activity (Figure 30-3).

Most average annual soil temperatures in the United States range from less than 32ºF (0ºC) to more than 72ºF (22ºC). Microbial activity is highest in soils that have a high average annual soil temperature and lowest in soils that have a low average temperature. Thus, microbial activity decreases or increases as the mean monthly soil temperature changes throughout the year. When applied to cold or frozen soils, agricultural manures mineralize very slowly, are difficult or impossible to incorporate, and are vulnerable to surface runoff and erosion. Potential agricultural manure contamination of surface water is highest when agricultural manure is applied under these conditions. Microbial activity also highly depends on the soil's moisture content (Figure 30-4).

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Soils that are dry throughout most of the growing season have a low organic matter mineralization rate. Microbial activity in these soils is greatest immediately after rainfall or irrigation events and decreases as soil moisture decreases. Conversely, soils that are moist throughout most of the growing season have higher microbial activity and greater capacity to mineralize manure. Wet soils that are saturated with water during the growing season have potentially lower microbial activity than moist soils. This lower microbial activity is not caused by a lack of soil moisture but is the result of low soil aeration when the soils are saturated.

Nitrogen (N)

Organic N is converted to inorganic N and made available for plant growth during the manure mineralization process. This conversion process is a two-way reaction that not only releases N but also consumes N.

When applied to soils, manure increases the energy or food supplies available to the soil microbial population. This energy supply stimulates soil microbial activity, which consumes more available N than the mineralization processes release. Thus, high microbial activity during initial manure mineralization can cause a reduction of available N below that needed for plant growth. Nitrogen deficiency also occurs if the manure mineralization cannot supply sufficient quantities of N to the plants during periods of rapid growth. This condition is most apparent in spring as the soil

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warms and crops exhibit a short period of N deficiency.

Ammonium N (NH_4+). This form of N is the initial by-product of organic N mineralization. Ammonium is adsorbed, or filtered, to soil particles through the cation exchange. It can be used by plants or microorganisms. Ammonium N is further oxidized by nitrifying bacteria to nitrate N.

Nitrate (NO_3-). This form of N is not strongly adsorbed to soil particles. Nitrate forms of soil N are susceptible to leaching and can leach out of the plant root zone before they can be used for plant growth. Nitrate can contaminate groundwater if leached below the soil root zone or transported off the field by runoff to surface water. Soils that have high permeability and intake rates, coarse texture, or shallow depth to a water table are the most susceptible to nitrate contamination of groundwater. Those soils that have low permeability and intake rate, fine texture, or steep slopes have a high runoff potential and are the most susceptible to N runoff and erosional losses.

Phosphorus (P)

Organic P in agricultural manures is made available for plant growth through the mineralization process. Phosphorus mobility depends on the P adsorption capacity of a soil. Soils that have slow permeability and high pH, lime, iron or aluminum oxides, amorphous materials, and organic matter content have the highest P adsorption capacity. Adsorbed P is considered unavailable for plant growth. Soil erosion and runoff can transport the P offsite and contaminate surface water. Conversely, soils that have high permeability, low pH, and low organic matter have low P adsorption capacity, allowing P to leach below the root zone. However, this soil condition seldom occurs.

Potassium, calcium, and magnesium

Potassium, calcium, and magnesium converted from organic to inorganic compounds during mineralization have similar reactions in the soil. Upon dissolution, they become cations that are attracted to negatively charged soil particles and soil organic matter. Potassium is less mobile than N and more mobile than P. Leaching losses of potassium are not significant and have little potential to contaminate groundwater. Calcium and magnesium can leach into groundwater or aquifers, but they do not constitute a hazard to water quality under good manure management practices.

Heavy metal and trace element

Heavy metals and trace elements are strongly adsorbed to clay particles or soil organic matter and have very little potential to contaminate groundwater supplies and aquifers. This immobilization is strongest in soils that have a high content of organic matter, pH greater than 6.0, and cation-exchange capacity of more than 5. However, application of organic manure containing high amounts of heavy metals can exceed the adsorptive capability of the soil and increase the potential for groundwater contamination.

Sandy soils that have low organic matter content and low pH have a lower potential for retention of heavy metals. These soils have the highest potential for heavy metal and trace element contamination of aquifers and groundwater. Surface water contamination from heavy metals and trace elements is a potential hazard if agricultural manures are applied to areas subject to a high rate of runoff or erosion.

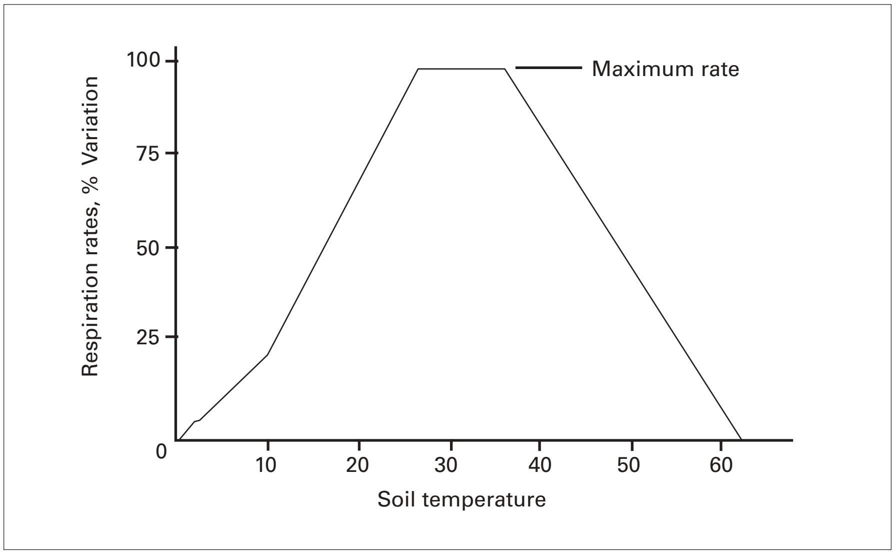

Figure 30-3. Relationship between microbial respiration rate and temperature.

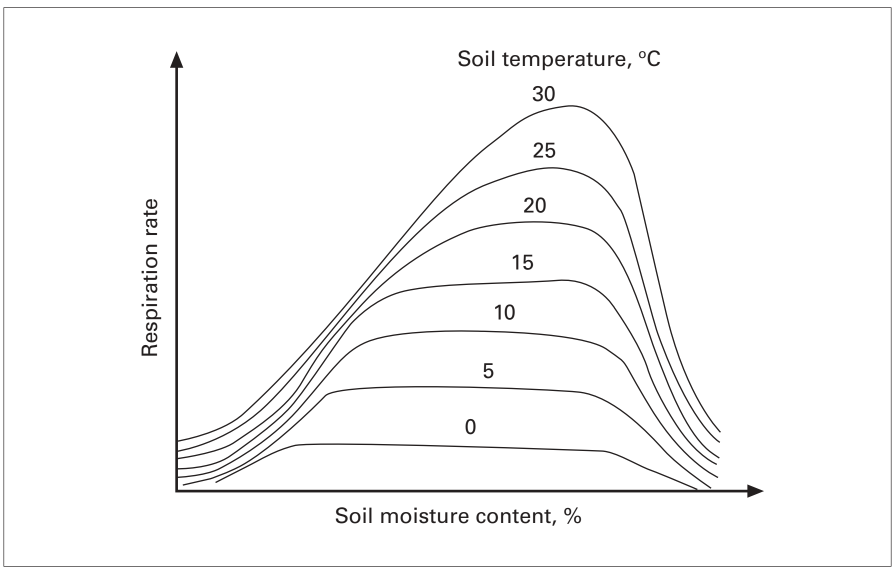

Figure 30-4. Relationship of microbial respiration rate to temperature and moisture.