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Soil Characteristics

Manure application practices involve the spreading, injection, incorporation, or irrigation of manure on, into, or upon land. The suitability, limitations, or hazards associated with these practices depend upon and are influenced by the geographical variability of the soil and soil properties within the application area.

The soil is a very effective manure treatment system if manures are applied at the proper rate. If the soil has been overloaded or if measures are not taken to adequately protect wells, groundwater contamination may result. The soil is a controlling factor in the groundwater recharge process because it may hold the water in soil pores, release it to plant roots or the atmosphere, or allow it to pass through to the lower layers and groundwater.

The soil can filter pollutants and prevent them from reaching groundwater. However, soils vary tremendously in their adsorption, or filtering, capacity. As a result, under some conditions, pollutants may take months or years to move from the land surface to the groundwater. Under other conditions, they can flow almost directly into the groundwater. An understanding of soil characteristics is essential in determining the potential for groundwater contamination in a given situation. The following soil characteristics are important in determining a soil's ability to treat manure products.

Available water capacity

Available water capacity is a measure of the soil's capacity to hold water in a form available to plants. It is a function of soil porosity, texture, structure, organic matter content, and salinity. Available soil water is estimated as the difference between soil water content at field capacity and the permanent wilting point. The available water capacity is generally expressed as the sum of available water in inches to a specified soil depth. Generally, this depth is 5 feet or the depth to a root-restricting layer, whichever is less. Available water capacity infers the capacity of a soil to store or retain soil water, liquid manure, or mineralized manure solids in the soil solution. Applying manure to land increases soil organic matter content, helps to stabilize soil structure, and enhances available water capacity.

A balance of air, water, and nutritive substances at a favorable temperature is important to a healthy microbial population and an effective filtration system. For example, overloading the filtration system with liquid manure that has high amounts of suspended solids causes clogging of soil pores and a reduction of soil hydraulic conductivity. Management and timing of manure applications are essential to maintaining soil filter systems. Climate, suspended solids in the manure, and cropping systems must be considered to maintain soil porosity and hydraulic conductivity.

The manure application rate should not exceed the long-term soil decomposition rate, which depends on soil temperature and moisture content. In areas where the soil temperature is warm for longer periods, the application rates may be higher if the crop uptake of nutrients is also higher. Periods of wetting and drying increase microbial decomposition and by-product uptake by the crop and decrease potential soil pore clogging. In areas where the temperature is warm for long periods, the application rates may be higher if crops or other means of using the by-products of manure decomposition are available. Tillage practices that maintain or improve soil tilth and reduce soil compaction and crusting should be included in the land application part of

agricultural manure management systems. These practices help to maintain soil permeability, infiltration, and aeration, which enhance the biological decomposition processes.

The relative proportion of sand, silt, and clay in a soil determines its texture. Sandy soils allow water to drain rapidly and limit the exposure time of manure nutrients to the crop roots. Soils with a high proportion of clay (clay soils are sticky when wet, and hard and clumpy when dry) are better suited for holding the manure materials until the crops can use the nutrients. As a result, groundwater contamination is less likely in clay soils.

Cation-exchange capacity

Cation-exchange capacity (CEC) is an index of the soil's capacity to exchange cations with the soil solution. It affects the ability of the soil to adsorb and retain cations and heavy metals. Cations are held to the soil particles by adsorption and can be returned to the soil solution for plant use by the exchange process.

Soils that have high CEC and organic matter can exchange and retain large amounts of cations released by the manure mineralization process. Conversely, soils in which the CEC is low have low potential for exchanging and retaining these manure materials. The potential for agricultural manure contamination of underlying groundwater and aquifers is highest for soils that have low CEC and lowest for those with high CEC. Soils that have high CEC can also have a low permeability rate, which increases the possibility of manure-contaminated runoff on sloping soils.

The limitations for solid and liquid manure applications are slight for soils that have a CEC of more than 15, moderate for those with a capacity of 5 to 15, and severe for those with a capacity less than 5. Underlying groundwater supplies and aquifers can become contaminated when manures are applied at high rates to soils that have moderate or severe limitations because of their CEC. Matching the amount and timeliness of crop nutrient uptake with the nutrients in manure applications can reduce the hazard for groundwater contamination.

Depth to groundwater

Depth to groundwater is important primarily because it determines the volume of soil through which a pollutant must travel before reaching the groundwater. It also determines the amount of time that a pollutant is in contact with the soil. Where the soil is fairly deep, the processes of filtration, absorption and adsorption, biodegradation, and volatilization that occur in the soil operate effectively. Conversely, shallow soils can adsorb only a limited amount of pollutants. The pollution potential increases where the soils are thin and the underlying bedrock is permeable, or where the water table is near the surface.

Flooding

Flooding is the temporary covering of the soil surface by flowing water. Standing or flowing water during and shortly after rain or snowmelt is not considered flooding. Flooding events transport surface-applied manure off the application site or field and deposit these materials in streams, rivers, lakes, and other surface water bodies.

Soils that have rare flooding potential (5 times or less in 100 years) have slight limitations for the application of manure. Occasional (5-50 times in 100 years) is a moderate limitation for manure application, and frequent flooding

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(50-100 times in 100 years) is a severe limitation.

Manure should be applied during the year when the probability of flooding is low. Liquid manure should be injected, and solid manure should be incorporated immediately after application. Incorporating and applying manures when the probability of flooding is low reduces the hazard to surface water.

Rock fragments

Rock fragments, stones, and boulders can restrict application equipment and affect manure incorporation. Incorporating manures that have high solids content may be difficult or impractical where

- Rock fragments between 3 and 10 inches in diameter make up more than 15%, by weight, (10%, by volume) of the soil.
- Stones and boulders more than 10 inches in diameter make up more than 5%, by weight, (3%, by volume) of the soil.

Because of this, manures applied to these areas may be transported offsite by runoff and have the potential to contaminate the adjacent surface water. Local evaluation of the site is required to determine if the size, shape, or distribution of the rock fragments, stones, and/or boulders will impede manure application or incorporation.

Intake rate

The intake rate is the rate at which water enters the soil surface. Soil porosity, bulk density, moisture content, texture, structure, and permeability of the surface layer influence initial water intake. Continued water intake rate is controlled by the permeability of underlying soil layers. If the applied manure has large quantities of suspended solids and is applied at high rates on soils that have high or moderate intake potential, soil macropore space can clog and the soil intake rate is reduced. Conversely, application and incorporation of manures to soils that have slow water intake potential can increase soil structure and porosity, improving the potential water intake rate. The short-term effect of application rates on soils that have a slow intake rate may be pore clogging and surface runoff.

Application rates that exceed the irrigation intake rate may result in surface runoff of manures, which have the potential to contaminate adjacent surface water. Limiting application rates to the recommended amount, using split applications, and applying only during the year when loss of moisture to the atmosphere exceeds precipitation can lessen aquifer and water table contamination.

Permeability rate

Permeability (hydraulic conductivity) is the quality of soil that enables water to move downward through the soil. Permeability rate is estimated from soil physical properties and is expressed in inches per hour. Permeability rates affect runoff, leaching, and decomposition rates of manures that are applied to or incorporated in the surface layer. Application and incorporation of manures improve soil surface intake and permeability; however, frequent applications at high rates can clog soil pores and reduce soil surface permeability and intake.

Manures applied to soils that have a permeability of less than 0.2 inch per hour should be incorporated (solids) or injected (liquids) into the soil,

reducing potential surface water contamination from erosion and runoff. Reduced rate and multiple applications of liquid manure are recommended for soils that have a permeability of more than 2 inches per hour. Application of manure near the time of nutrient utilization of growing crops should achieve similar results. Reducing the rate of application and using split applications of manure solids on soils that have severe permeability limitations can reduce the potential for contamination of shallow aquifers.

Soil pH

Soil pH affects plant nutrient availability, manure decomposition rates, and adsorption of heavy metals. Soils in which the surface pH is less than 6.0 have lower potential for plant growth (grain and forage crops) and low heavy metal adsorption.

Limitations and recommendations are based on the lowest pH value of the surface layer. Limitations for the application of agricultural manure are slight if the pH in the surface layer is more than 6, moderate if it is 5 to 6, and severe if it is less than 5. Continuous, high application rates of manure can reduce soil pH. If large amounts of manure are applied to small fields or land tracts, the soil pH should be monitored, preventing its reduction to levels that affect plant growth.

Ponding

Ponding is standing water in a closed depression that is removed only by percolation, transpiration, or evaporation. Manure applied to soils that are ponded have a very high potential for contaminating the surface water. Manure application on these soils should be avoided if possible. Low field areas of these soils can become a collection point for salts.

Salinity

Salinity is the concentration of dissolved salts in the soil solution and is related to electric conductivity. Electrical conductivity is the standard measure of soil salinity and is recorded as mmhos/cm. High soil salinity interferes with a plant's ability to absorb water from the soil and to exchange plant nutrients. This interference reduces plant growth and seed germination and limits the choice of crops that can be successfully grown. If soil salinity is a potential hazard or limitation, crops that have high tolerance to salinity should be used in the manure management system.

Salinity ratings are determined by the electric conductivity of the soil surface. Limitations for the application of manures are very slight if salinity is measured as less than 4 mmhos/cm, slight if it is 4 to 8 mmhos/cm, moderate if 8 to 16 mmhos/cm, and severe if more than 16 mmhos/cm.

Soils that have moderate salinity limitations affect the germination of some plants and affect the choice of crops that can be grown. Manures that have a high content of salt can be applied to moderately rated soils, but applications should be rotated among fields and rates should be reduced, preventing an increase in soil salinity and further degradation of plant growth. Applying manures that are high in salt to soils that have a severe rating should be avoided, preventing an increase in soil salinity and further inhibition of plant growth and organic matter decomposition.

Manures that have a low salt content and a high carbon-to-nitrogen (C:N) ratio can be applied and will have a beneficial impact on soils that have a

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moderate or severe salinity rating. Application of low-salt, high C:N ratio manures to these soils improves water intake, permeability, available water capacity, and structure. It also reduces salt toxicity to plants. Salts are moved through soils by water movement. Salt buildup may be more of an issue in arid climates or soils with poor permeability.

Slope

Slope is the inclination of the soil surface measured from a horizontal plane and expressed as a percentage. The slope influences runoff velocity, erosion, and the ease with which machinery can be used. Steep slopes limit application methods, rates, and machinery choices. As slopes become steeper, rainfall events will increase soil and manure erosion.

Limitations for the application of manures are slight if the slope is less than 8%, moderate if it is 8% to 15%, and severe if it is more than 15%. Manure applied to soils that have moderate limitations should be incorporated. Incorporation minimizes erosion and transport of manure materials by runoff, reducing the potential for surface water contamination.

Soils that have severe slope limitations have limited cropping potential and are subject to excessive runoff and erosion. Permanent ground covers or forests may be utilized to absorb nutrients and reduce erosion and runoff. Conservation practices that reduce potential water erosion and runoff similarly reduce erosion and transport of manures and therefore should be incorporated into the manure management system.