

Relating Research Results to Sludge Guidelines for Michigan's Forests

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ABSTRACT Guidelines for application of wastewater sludge to forest land in Michigan were developed by the Department of Natural Resources from research studies on small plots and large-scale demonstration sites. Growth response and groundwater quality data provided a basis for estimating appropriate application rates, selecting suitable application sites, and developing proper application procedures. Balancing nutrient additions with the assimilation capacity of each forest ecosystem was found to enhance site productivity while minimizing **nutrient** enrichment of groundwater. This principle, referred to as the periodic agronomic rate, is similar to the already widely accepted annual agronomic rate currently in place as policy for sludge application on cropland. The periodic agronomic rate, however, recognizes the unique nutrient cycling and long-term storage potential of aggrading forests. Sludge nutrient application rates and operational procedures reflect the need for a conservative approach in protecting the environment and public health when implementing regulatory programs that employ new technology.

In the process of developing regulatory direction for land application of wastewater sludge, it is important to draw upon the available research data and management **experience** that will aid in developing guidelines that provide adequate protection for environmental quality and the public health. In Michigan, a statewide program based on state-of-the-art knowledge regulates land application of sludge through a system of permits issued by the Department of Natural Resources (DNR). This paper describes how available research and development information has been used by DNR to formulate **proposed** guidelines for the forest land application option.

State Groundwater Rules specify that "quality degradation of any usable aquifer is prohibited" (MDNR 1980). Groundwater in the northern forested region of the state is widely used as a domestic water source with minimal treatment. Furthermore, the water yielded by forested watersheds is normally expected to be of high quality. Therefore, any surface land management activity is required by law to have minimal effect on a usable phreatic aquifer.

While some regulators have interpreted the legislative mandate to mean "zero discharge" to any usable aquifer, foresters and agronomists have, from their understanding of the normal rates of elemental flux in natural biogeochemical cycles, argued for a less restrictive policy of quality control for the groundwater. Plans **for** land application of sludge should consider rates of addition appropriate to each ecosystem's capacity for nutrient and trace element assimilation. Available research on forest land application indicates that excessive sludge applications, which result in available nitrogen at levels

greater than site assimilation, storage, and **denitrification** capacities, can lead to **groundwater** enrichment by nitrate leaching. Balancing sludge application rates with rates of volatilization, mineralization, **nitrification**, denitrification, soil storage, and plant **uptake** is central to minimizing potentially adverse effects on groundwater.

EXISTING GUIDELINES

Existing guidelines for land application of sludge have been developed with primary emphasis on **cropland** (MDNR 1982). Since the **mid-1970s**, application to farmland has been the most frequently selected sludge recycling option. Under the requirements of the NPDES permit issued for operation of each municipal and industrial facility, a Program for Effective Residuals Management (PERM) must be drafted by the waste generator which outlines the proposed sludge management procedures.

The PERM must contain the following information: (1) a description of the treatment processes used and an estimate of the monthly production of sludge solids, (2) a list and description of all facility storage structures, including the capacity of each, (3) a **description** of the sludge transportation equipment available, (4) application site data, including maps, site dimensions, ownership, and significant site modifications, (5) a list of site management activities related to method and timing of sludge application, crops to be grown, and harvest frequency, (6) proposed rates of sludge application based on sludge chemical composition, soil fertility needs, and crop nutrient needs, (7) a comprehensive chemical analysis of the sludge, (8) a monitoring schedule to include frequency of analyses for sludge and soil (groundwater and plant tissue if more intensive monitoring is indicated), and (9) a list of contingency options. As long as an agronomic rate of sludge nutrient additions is used for land application, the state requirement for filing a **hydrogeological** study and a groundwater monitoring plan for each site is usually waived.

In conducting a local sludge management program under a state approved **PERM**, additional guidelines related to use on croplands are to be observed. Although primarily aimed at abating pollution of surface and groundwaters, these best management practices are also intended to minimize problems with sludge odors and citizen complaints.

These additional requirements include: (1) Sound farming practices are to be used. (2) Sludge use on soils with high available phosphorus levels (greater than 336 kg/ha or **300 lb/acre**) is to be avoided. (3) Surface-applied liquid or solid sludge is to be incorporated into the soil within 48 hours of application. Liquid sludge applied to forage crops **within** 7 days of cutting is exempt from this requirement. (4) Grazing is prohibited for 30 days following sludge application. (5) For surface application of sludge, isolation distances of 152 m (500 ft) to homes and commercial buildings and 46 m (150 ft) to wells, surface waters, public roads, and property lines must be observed. (6) For subsurface application of sludge, isolation distances of 30 m (100 ft) to homes and commercial buildings, 46 m (150 ft) to wells, 15 m (50 ft) to surface waters, and 8 m (25 ft) to roads and property lines must be observed. (7) Maximum slope limitation for surface-applied sludge is **6%**, and for subsurface-applied sludge 12%. (8) Use of sludge is to be avoided when the water table is less than 76 cm (30 inches) below the soil surface. (9) Sludge applications to frozen or snow-covered croplands are not generally approved.

The sludge management activities of each generator facility are monitored by the required submission of monthly operation reports, which provide detailed information for each period of sludge application to land. For each site receiving sludge a Waste **Dis-**

posal Sheet (Figure 1) is completed, to document placement of the material and track the on-site accumulation of nutrients and trace elements.

Because of limited experience with silvicultural use of wastewater sludge, forest land application programs proposed by municipalities and industries have been evaluated on a case-by-case basis. However, recent research has provided sufficient data for state specialists to formulate guidelines for forest land applications. Although sludge application programs developed for forests must suit the individual aims of the generator and the land manager, meeting their objectives must be subordinated to sufficient protection for the environment and public health.

Research has shown that nitrate-N leaching is usually the factor limiting sludge application rates for most forest ecosystems (Brockway and Urie 1983). Rates of nitrogen volatilization, mineralization, **nitrification**, denitrification, and plant assimilation will all affect the allowable maximum application rate in each forest type. However, nitrogen assimilation rates in fertilized forests have received much less attention than those of natural, unamended ecosystems. First-year assimilation rates can be estimated from available research data for liquid sludge applications in several forest types (Urie et al. 1984).

The timing of repeated sludge applications will depend on the rate at which organic nitrogen in the sludge solids remaining from earlier treatments is mineralized. This rate is known to vary, depending on the treatment process used during sludge generation (Sommers and Nelson 1981). The nitrogen-enriched forest floor will undergo more rapid decomposition, and the native organic matter may also become mineralized more rapidly. Although available data are sketchy on these dynamics, nitrogen availability on sludge-treated forest sites and the need for sludge nitrogen inputs will be determined by the "new" nitrogen cycle.

Annual nitrogen and cumulative heavy metal loading rates are considered in sludge application guidelines for cropland. No criteria based on demonstrated toxicity currently exist for placing limits on heavy metal application rates in forests. State regulatory agencies generally discourage land application of sludges containing unusually high levels of toxicants. Although relatively high applications of heavy metals have been made to forests with no measurable adverse effects (Brockway 1983), heavy metal mobility is expected to be somewhat greater in the acid soils typically present on northern forest sites than in less acidic agricultural soils.

Groundwater monitoring for the first generation of operational forest land application programs, though expensive, may be required to develop public confidence in the new technology. This may be especially true when an added margin of safety is needed for projects operated in sensitive ecosystems. Monitoring will also serve to evaluate the rather conservative restrictions usually in effect during the early tentative stages of a new program. Using this additional body of experience, guidelines can be later refined to more closely match site assimilation capacity to sludge application rates.

PROPOSED GUIDELINES

A policy of sludge application for forest land is proposed which is consistent with the statutory directive of nondegradation of usable aquifers. Similar to the annual agronomic rate currently in use for cropland, this proposal is one of a periodic agronomic rate that supplies the nutrient needs of the forest crop for the interval (averaging five years)

between sludge applications. Nutrient additions in this manner will fully utilize the assimilation and storage capacities of the forest environment. Sludge nitrogen additions are limited by the rates of volatilization loss, mineralization, nitrification, denitrification loss, plant uptake, and soil storage so as to minimize leaching losses to groundwater.

Operational sludge application rates must be individually computed for each site, based on specific sludge nutrient and trace element concentrations, sludge stabilization method, and the nutrient uptake potential of the candidate forest type. Ammonia volatilization losses following land application are expected to vary from 20 to 60% (Sommers and Nelson 1981) depending on temperature and wind conditions. An average of **50% of** the ammonia-N is estimated to be available in the first year. Sludge stabilization process provides an indication of the nitrogen mineralization rate (Table 1). Nitrogen uptake rate

TABLE 1. Nitrogen mineralization rates in the first year following sludge application (Sommers and Nelson 1981).

Sludge Type	Nitrogen Mineralization Rate (%)
Waste activated	42
Primary	29
Primary plus CaO	28
Aerobic digested	25
Anaerobic digested	15
Composted	9
Primary, wet air oxidized	3

is a prominent factor determining the periodic agronomic rate of sludge application. Those for several Michigan forests are listed from available literature (Table 2). Using these data, a sludge application rate that provides a substantial input of fertilizing nutrients and an adequate level of protection for the groundwater is computed.

Site selection criteria are the second major area of sludge management planning concern, since they determine the antecedent conditions within which program activities will be conducted. Selecting sites according to these guidelines will aid in management operation and minimize adverse effects on the forest environment.

The required information for and characteristics of a candidate forest site appropriate for land application of sludge are as follows: (1) Provide background data concerning site location (plat map), proximity to structures, roads, and drainage ways (aerial photo), soil types (soil survey map), soil fertility, site history, significant site modifications, stand composition, age, basal area, stocking (cover type map), and understory. (2) Soils should be no less than somewhat poorly drained, and the water table must be at least 76 cm (30 inches) below the soil surface at the time of sludge application. (3) Maximum slope limitation for surface-applied sludge is 6%. (4) For surface application of sludge, isolation distances of 152 m (500 ft) to homes and commercial buildings and 46 m (150 ft) to wells, surface waters, public roads, and property lines must be observed.

If sludge application to frozen or snow-covered soil in winter is proposed, these additional considerations must be met for each site: (1) Site access trails must not exceed 2% slope. (2) An isolation distance of 152 m (500 ft) to homes, commercial buildings, wells, surface waters, public roads, and property lines must be observed. (3) Soils should be no

TABLE 2. Recommended sludge available nitrogen (AVAN) application rates for forests in Michigan, over a five-year retreatment interval.

Species	Age (years)	Sludge Application Rate		Nitrate Leached (kg/ha·yr)
		Dry solids (Mg/ha·5 yrs)	AVAN (kg/ha·yr)	
Aspen	0 to 5	9	56	17
Aspen	5 to 20	18	112	28
Aspen	over 20	9	56	17
Northern hardwoods	0 to 10	7	45	17
Northern hardwoods	10 to 30	14	90	24
Northern hardwoods	over 30	7	45	15
Oak and hickory	0 to 10	9	56	17
Oak and hickory	10 to 30	18	112	28
Oak and hickory	over 30	9	56	17
Scrub oak	0 to 20	5	34	12
Scrub oak	over 20	9	56	17
Red, white, jack pine	0 to 10	9	56	17
Red, white, jack pine	10 to 30	5	34	12
Red, white, jack pine	over 30	4	22	10
Spruce and fir	0 to 10	7	45	15
Spruce and fir	10 to 30	5	34	12
Spruce and fir	over 30	4	22	10
Northern white cedar	0 to 20	9	56	15
Northern white cedar	over 20	4	22	10

less than moderately well drained with no reasonable probability of surface runoff of sludge-applied solids. (4) The stand must be fully stocked with canopy cover of no less than 60%. (5) Liquid sludge application rates are limited to a maximum of **280,500 liters per hectare (10,000 gallons per acre)**. (6) There must be no established winter recreation uses on the site. (7) Each site must be selected by September 15 prior to the winter during which it is proposed for sludge application and clearly identified by signs that caution entry.

In addition to information on application rates and site selection, several points regarding management activities should be noted. Surface application of liquid, well-digested sludge is encouraged for use in Michigan forests. Research in other states (Richter et al. 1982, Wells et al. 1984) indicates that dewatered sludges have much lower rates of biological activity and provide little immediate benefit to forest nutrition, for they remain relatively inert while perched on the forest litter for long periods. Federal regulations (U.S. EPA 1979) require that land-applied sludge be properly stabilized by a process that significantly reduces pathogens to protect public health. This point is particularly pertinent where sludges are surface applied on publicly owned forest land, because well-stabilized sludges are also less likely to produce offensive odors.

The method of liquid application should effectively distribute a uniform cover of sludge on the forest floor. This will reduce the possibility of creating overloaded microsites, which may function as points of high nitrate discharge to groundwater. Equipment should be selected and operated to minimize damage to soil and standing trees. Such measures will diminish the risk of soil compaction, infection of trees through scars on stems or roots, and infestation by insects.

SUMMARY

Guidelines for application of wastewater sludge to Michigan's forest lands are proposed that include an empirical basis for estimating appropriate application rates, criteria for selecting suitable application sites, and general guidance for overall application program operation. The central approach of balancing nitrogen additions to the assimilation capacity of each forest type represents a rational way of stimulating biological productivity while ensuring adequate protection for the environment and the public health. The principle of balance, referred to as the periodic agronomic rate of application, is patterned closely after the already widely accepted annual agronomic rate currently in place as policy for sludge applications to cropland. The distinguishing feature between them lies in recognition of the unique nutrient cycling and long-term storage potential of aggrading forest ecosystems. Regional research data have been used to establish very conservative estimates of nitrogen assimilation for numerous forest types. These were established in recognition of the need to maintain continued yields of high quality water from forested watersheds. As knowledge grows with increasing experience in the area of forest land sludge applications, revised estimates of nutrient and trace element assimilation capacities for the numerous forest environments of Michigan will facilitate development of more finely tuned guidelines for maximizing forest site benefits and obtaining the lowest sludge nutrient recycling costs consistent with environmental protection.

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