



Guidance on Land Treatment of Nutrients in Wastewater, with Emphasis on Nitrogen

Background

In Washington State, waste water from some municipalities and industries is applied to cropland to obtain biological treatment. Ecology's Water Quality Program permits the land treatment of waste water provided all known, available, and reasonable methods of prevention, control, and treatment (AKART) is described and approved in an engineering report. Documents have been developed to help define AKART, guide site selection, and design land application treatment systems (Ecology, 1993; Ecology, 1996; Department of Health, 1994). The treatment process (AKART) and treatment capacity are determined in an engineering report that follows Chapter 173-240 WAC (Construction of Wastewater Treatment Facilities) and the Ground Water Quality Standards, Chapter 173-200 WAC (Water Quality Standards for Ground Waters of the State of Washington). Currently, Ecology approves as AKART the design, and operation and maintenance for land treatment systems that includes: 1) the application of wastewater and its nutrients at rates, times, and durations that do not exceed the crop's agronomic rates, and 2) the storage of wastewater in properly lined lagoons that is produced in excess of the crop's requirement or outside of the growing season.

A well-managed land treatment system limits wastewater application to rates that do not exceed the treatment capacity of the crop or soil and minimizes adverse impacts to groundwater quality by all contaminants. Management of the timing and volume of wastewater application is required to avoid exceeding the treatment capacity of the crop or soil.

This guidance document refers to management and treatment of nutrients in wastewater, but emphasizes nitrogen. Ecology uses the term nutrients in the broad sense. However, among the general class of nutrients readily available and used by crops, only nitrate is specifically regulated in the Ground Water Quality Standards and would be considered as a design limiting contaminant at most land treatment sites. Other nutrients discharged to a land treatment site can create water quality or other problems and, as a result, may require careful management. For example, nitrogen and phosphorus discharged from a land treatment site to a nearby surface water body via hydraulic continuity can promote algal growth and eutrophication; excess potassium in the soil can cause grass tetany in grazing animals; and sodium in drinking water is a concern for people on low sodium diets.

A viable crop must be established and maintained to achieve the level of treatment necessary to protect ground water. Ecology recognizes that in some circumstances maintenance of a viable crop for treatment of nutrients requires periodic flushing of salts from the crop root zone. Salt flushing should not conflict with the requirement to minimize leaching of contaminants below the crop root zone and to comply with the Ground Water Quality Standards. Through AKART, careful water management,

and pollution prevention these requirements should be achievable at a properly designed and managed land treatment site.

Significance of Agronomic Rate

The primary goal of a land treatment system is to achieve the level of treatment necessary to meet the requirements of the Ground Water Quality Standards. A fundamental requirement of the Ground Water Quality Standards is that AKART must be applied to all discharges to ground water. For nutrients, AKART includes two basic concepts: 1) that nutrient uptake by the crop is maximized and leaching below the root zone to the uppermost aquifer is minimized, and 2) that the land treatment system provides maximum treatment when the application rate does not exceed the agronomic rate for the design limiting contaminant as identified in the design engineering report.

The term agronomic rate, when used for land treatment, is defined as:

Rate at which a viable crop can be maintained and there is minimal leaching of chemicals downwards below the root zone. Crops should be managed for maximum nutrient uptake when used for wastewater treatment. (Ecology, 1996)

The most common use of agronomic rate is applied to certain contaminants, such as nutrients, which can be readily treated through crop uptake and bacterial or biological processes that naturally occur in the soil column. The capacity of the crop and soil to treat these contaminants is determined by the design engineering report and is based on reasonable assumptions or site specific information regarding agronomic rates, mineralization of organics, nitrification/denitrification, volatilization, and irrigation efficiency and uniformity. For some contaminants there is literature to support the determination of agronomic rate. Treatment is substantiated from information given to Ecology in an annual irrigation and crop management plan and a monitoring plan that are conditions of the discharger's state waste discharge permit. Monitoring may be required for waste water, soils, crops, and ground water.

Wastewater Management

A critical element in defining AKART and achieving treatment of waste water to meet the Ground Water Quality Standards is management of the waste water during the non-growing season. This goes beyond water management using a checkbook approach. For land treatment systems, the goal is to fully apply AKART to protect groundwater quality at the facility and for the beneficial use by neighboring landowners. This means that the annual distribution of waste water applied to the land treatment site is confined to the growing season when nutrients are readily treated by crop uptake and soil microbial activity. These treatment processes are diminished by low temperatures during the non growing season. Ecology has collected and interpreted data from soils monitoring and from groundwater monitoring at a number of permitted land treatment facilities around the state. The period of record for some sites is more than a dozen years. Ecology's evaluation of these monitoring data shows a correlation between excessive, non growing season wastewater application and groundwater contamination. Conversely, when facilities have converted from year round application to seasonal application, groundwater quality has improved.

Some soil moisture is lost during the non-growing season through evapotranspiration during temporary warm periods. Replacement of this moisture is a reasonable sprayfield management tool that maintains

the viability of the crop. The problem is that many facilities operate year round. As a result, the volume of water necessary to replenish and maintain adequate soil moisture during the non-growing season is likely to be small compared to the volume of waste water actually generated by the facility. Further, Washington's climate regime of winter precipitation can be expected to provide some, if not all, of this soil moisture.

This means that wastewater storage or alternative methods of treatment and discharge may be needed for periods when land application may be precluded by climatic or other conditions. Among the options available for management of excess waste water are storage in a properly constructed lined lagoon, discharge to a surface water body in accordance with Chapter 173-201A WAC and Chapter 173-220 WAC, or discharge to a publically owned treatment works (POTW) in accordance with Chapter 173-216 WAC. All of these options have been approved and permitted by Ecology and are being used by different dischargers.

The factors cited above were among those considered during the preparation of Ecology's land application design guidance (Ecology, 1993.) and in the determination of AKART.

Nitrogen Fate and Transport

A Washington State University report, *Nitrogen Use by Crops and the Fate of Nitrogen in the Soil and Vadose Zone* (WSU 2000), was completed with EPA grant funding through Ecology. The report is an extensive literature review on nitrogen dynamics in the soil, especially as it relates to the application of high strength organic waste waters to land treatment systems. It provides technical background information on nitrogen use by crops and describes the complex interactions between crops, soils, nitrogen, and water.

A vast majority of the literature contained in the report is from research and studies conducted outside the state of Washington. However, given the diversity of crops and soil systems in the state, some general principles and recommendations (WSU 2000) were developed for the use of nitrogen by crops, and the fate of nitrogen in the soil and vadose zone:

- The estimation of the agronomic rate for a crop must factor in all sources of nitrogen available during the growing season.
- All nitrogen applied to the soil, that is not volatilized, will eventually convert to nitrate.
- Soil nitrogen that moves below the root zone will eventually leach to the ground water as nitrate.
- Denitrification may reduce nitrate loading to ground water under some conditions, though it is of little importance in well drained soils.
- Nitrogen applied at agronomic rates will minimize the buildup of soil organic nitrogen.
- Wastes applied substantially before or after maximum crop demand may result in nitrate leaching.
- Organic wastes applied during the non-growing season will partially or totally convert to nitrate before the next growing season.
- Nitrates leached beyond the root depths of the crop to be grown during the following season will be susceptible for transport to the ground water.

- Steps should be taken to minimize movement of nitrogen below the root zone during the growing and non-growing season.
- Applying organic wastes during the non-growing season has an inherent risk in terms of leaching nitrogen to the ground water.
- The use of storage facilities to minimize waste applications during the non-growing season is a safe alternative.

The report (WSU 2000) does not completely rule out the application of waste water outside of the growing season. However, from the literature it is apparent that the many uncertainties associated with nitrogen dynamics in the vadose zone support a position that applying waste water to crops and soil systems during the non-growing season is not reliably protective of ground water.

Conclusions

Nitrogen processes are complex and difficult to precisely control or predict in the environment. Nitrate is the most chemically stable form of the nitrogen species and other forms of nitrogen readily convert to nitrate in the environment. Nitrate is also the most mobile nitrogen species and moves readily with water through the subsurface. Once nitrogen is applied to the soils, the grower must address this mobility through careful management of the land treatment site to avoid groundwater contamination. The diversity of climates and soils in Washington State combined with cropping and irrigation practices influence the fate of nitrogen once applied to the soil. Ecology concludes that nitrogen applied in the form of ammonia or organic nitrogen is likely to convert to nitrate during the time of the year when it is not adequately treated by the crop and, under excessive hydraulic load, will leach out of the soils and migrate to ground water.

Ecology has extensive experience reviewing soil and groundwater quality data at land treatment sites in Washington State. Based on the evidence presented in the WSU report and Ecology's experience with land treatment systems, Ecology concludes that the current AKART definition addresses the many uncertainties and potential negative consequences for groundwater quality associated with the fate and transport of nitrogen in the vadose zone, especially during the non-growing season.

Ecology will consider site specific demonstrations of innovative approaches to achieving treatment of nitrogen in waste water during the non growing season that are determined to be equivalent in effectiveness for protecting groundwater quality to the current AKART approach. Lacking such determination, Ecology concludes that applying waste water to crops and soil systems for the purpose of land treatment of nutrients in waste water during the non-growing season does not reliably protect groundwater quality, and therefore does not meet the AKART requirement for permit issuance according to the Ground Water Quality Standards.

Bibliography

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Washington Department of Health. 1994. Design Criteria for Municipal Wastewater Land Treatment Systems for Public Health Protection.

Washington State University. 2000. Nitrogen Use by Crops and the Fate of Nitrogen in the Soil and Vadose Zone.

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