Denitrification of tile-drain effluent: Technology Summary

Proven and experimental technologies for full-scale, on-field applications.

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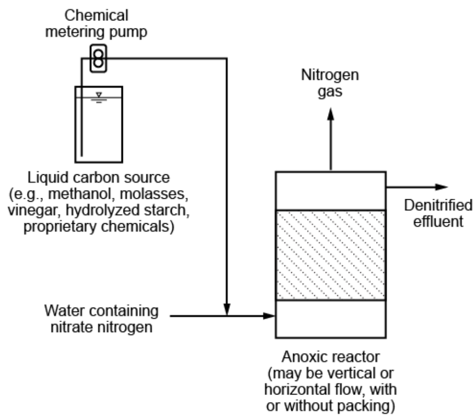
ANOXIC REACTOR WITH CHEMICAL FEED

Accomplishing biological denitrification by chemical feed of a carbon source is a common practice in wastewater treatment. There are many readily available and proprietary chemicals available that can be used as a carbon source, including methanol, molasses, acetic acid, and various sugars/starches. The basic process consists of blending the carbon source with the water containing nitrate and retaining the mixture under anoxic conditions for enough time for the reaction to take place. The addition of media and/or mixing increases the reaction rate. Views of an anoxic denitrification process are shown on Fig. 1.



(a)

(b)

Figure 1
Views of anoxic denitrification with chemical feed process (a) process flow diagram and (b) typical installation, www.aquapoint.com

Process Notes

Type: Biological
Estimated footprint: ~ 200 ft^2 not including process tanks.
Estimated initial cost: $15,000
Operation and maintenance: moderate

Advantages

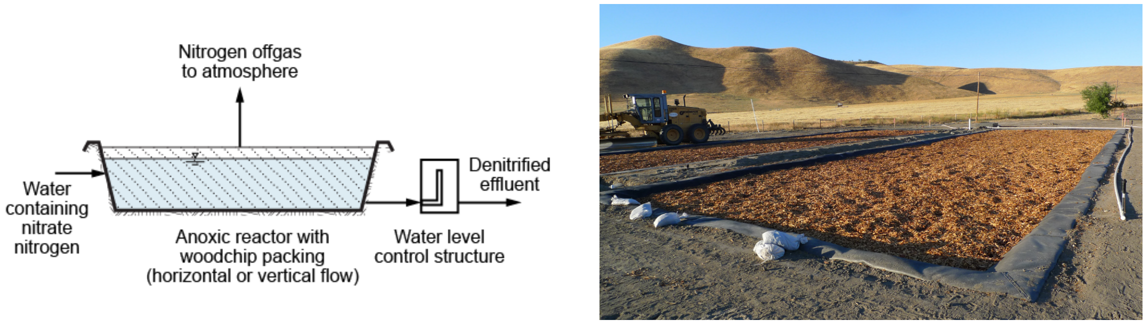
- Proven technology but needs to be evaluated for specific case of tile drain systems
- Highest removal rates in fluidized bed and mixed suspended growth systems
- Pre-engineered systems may be purchased
- Removal rates up to 160 g N/m^3-h
- Process tanks can be located below, or above ground surface

Disadvantages

- Need to replenish chemical on a regular basis.
- Some chemicals are hazardous (e.g., methanol).
- May need to reduce effluent carbon.

ANOXIC WOODCHIP REACTOR, AT-GRADE

At-grade anoxic woodchip reactors are perhaps the easiest to construct as they do not require any supplemental power, chemical feed, or proprietary equipment. Installation is similar to that of a lined shallow pond, with only a few additional plumbing items, such as a water level control structure, inlet distribution piping, and effluent collection. In addition, the operation and maintenance is among the lowest of any technology. Views of an at-grade anoxic woodchip reactor are presented on Fig. 2.



(a) (b)

Figure 2
Views of at-grade reactor (a) process flow diagram, Leverenz et al., 2010 and (b) full-scale reactor

Process Notes

Type: Biological
Estimated footprint: ~ 4000 ft^2
Estimated initial cost: $20,000
Operation and maintenance: minimal

Advantages

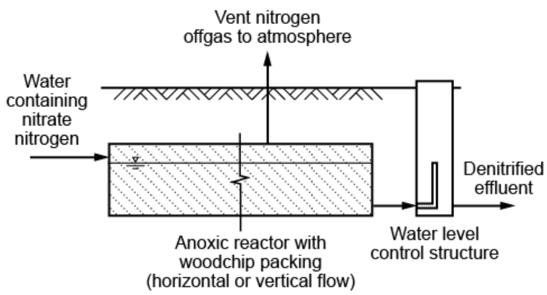
· Proven technology but needs to be evaluated for specific case of tile drain systems
· Can be integrated into marginal lands near terminus of existing tile drain system
· Use of plants as indicators of treatment performance (optional)
· Can assume zero order kinetics and 10 g N/m^3-d for initial sizing

Disadvantages

· May be space restrictions
· May require pump to lift water to ground surface
· Requires some degree of flow equalization to ensure performance
· Need to manage flush of dissolved carbon that continues for one to two months after reactor startup
· Woodchip media lifespan has not been established as longest operating systems are about 10 yr old but have not been exhausted.

ANOXIC REACTOR WITH WOODCHIPS, BELOW GRADE

The bacteria that carry out the denitrification reaction require a carbon source. The carbon source can be present in the water or added as a liquid or solid. Woodchips, sawdust, and compost have all been found to be excellent sources of carbon for denitrifiers. The reactors must be relatively large because of the slow release of carbon from submerged woodchips. Existing processes have been found to operate for more than 10 yr without woodchip media replacement. Views of subsurface reactors are shown on Fig. 3.



(a)

(b)

Figure 3
Views of subsurface denitrification reactors process (a) process flow diagram, Leverenz et al., 2010 and (b) industrial application, www.johnstonculvert.com

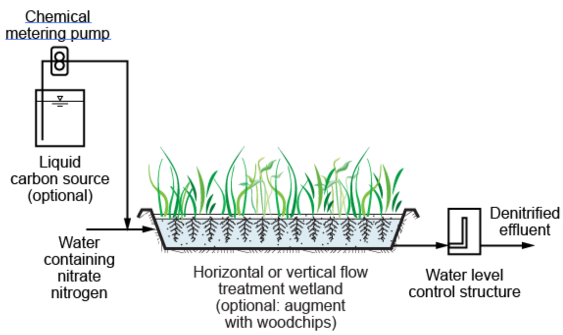
Process Notes
Type: Biological
Estimated footprint: ~ 4000 ft^2
Estimated initial cost: $35,000
Operation and maintenance: low/moderate

Advantages
- Proven technology but needs to be evaluated for specific case of tile drain systems
- Easier to site because it will not interfere with surface operations
- Can use 5 to 10 g N/m^3-d for initial sizing
- Large underground stormwater storage systems are commercially available and could be adapted to denitrification reactors.

Disadvantages
- Equipment and methods to install need to be developed
- Must unearth the system to perform maintenance or replace woodchips.
- Requires some degree of flow equalization to ensure performance
- Need to manage flush of dissolved carbon that continues for one to two months after reactor startup
- Woodchip media lifespan has not been established as longest operating systems are about 10 yr old but have not been exhausted.

HYBRID CONSTRUCTED WETLAND

A number of contructed wetlands have been built for the treatment of wastewater and stormwater, however, the potential for nutrient removal is limited to plant uptake, which is low typically. The rate of nitrogen removal can be enhanced by application of the techniques described previously, i.e., chemical or solid carbon supplements. An advantage of the plants in the system is supplemental nitrogen uptake, and the use of plants as a bioindicator of system performance. When the system is effectively removing nitrate the plants will appear yellow and frail. Views of a hybrid anoxic wetland reactor are presented on Fig. 4.



(a) (b)

Figure 4
Views of hybrid constructed wetland process (a) process flow diagram, Leverenz et al., 2010 and (b) field-scale application, www.uvm.edu

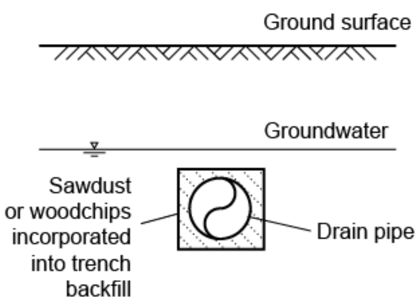
Process Notes
Type: Biological
Estimated footprint: 400 (chemical feed) to 4000 ft^2 (woodchips)
Estimated initial cost: $20,000
Operation and maintenance: low

Advantages
· Can work if augmented with suitable organic carbon source (liquid or solid phase)

Disadvantages
· May be space restrictions or concerns about the creation of habitat.
· Requires pump to lift water to ground surface
· Requires some degree of flow equalization to ensure performance.

AUGMENTED TILE DRAIN TRENCH BACKFILL (*IN SITU*)

The anoxic denitrification reactions can be incorporated into the design of the tile drain system is organic matter is mixed into the soil used to backfill around the drainage pipes. While this concept is largely unproven, there is sufficient anecdotal evidence to justify pilot testing. Views of an anoxic tile drain system are shown on Fig. 5.



(a)

(b)

Figure 5
Views of augmented tile drainage treatment process (a) process flow diagram and (b) drain installation, agebb.missouri.edu.

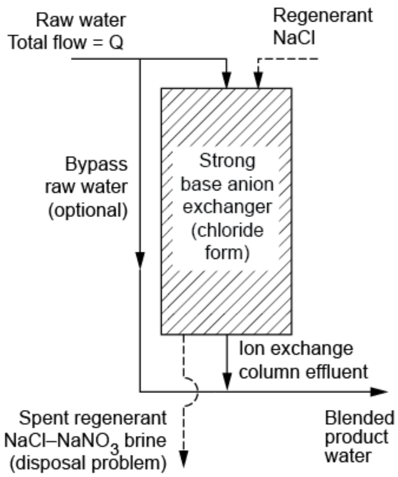
Process Notes
Type: Biological
Estimated footprint: N/A
Estimated initial cost: unknown, expected to be inexpensive if installation technique is developed
Operation and maintenance: low

Advantages
- Potentially inexpensive system.
- Reasonable chance that this approach could be effective, but will require pilot testing to develop design information.
- Zero space required
- Minimal changes to existing tile-drain system design.

Disadvantages
- Not proven, although there may be some information from related systems from mid-western US.
- Must be installed when tile drain is installed
- Performance may be unpredictable (without pilot testing and incorporation of appropriate process control devices).
- Equipment and methods to install need to be developed.
- Woodchip media lifespan has not been established as longest operating systems are about 10 yr old but have not been exhausted (however, note tile-drain operational life-span ~ 10 – 20 years).

ION EXCHANGE

In the ion exchange process, ions are sorbed onto a charged resin. As ions are sorbed to the resin, weakly bound ions are displaced. Periodically, the sorbed ions must be washed off of the resin using another solution known as a regenerant, which also replenishes the weakly bound exchange ions. The ions removed from the resin during regeneration would contain a high concentration of nitrate, which could be recovered. Images of an ion exchange process are shown on Fig. 6.



(a)

(b)

Figure 6
Views of ion exchange process (a) process flow diagram, Crittenden et al., 2007 and (b) industrial application, www.remco.com

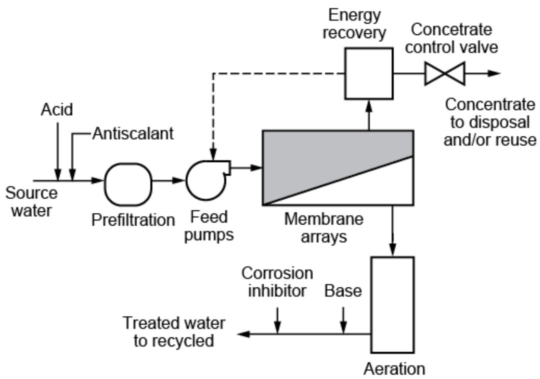
Process Notes
Type: Physical-chemical
Estimated footprint: 200 ft^2 including ion exchange contactors and other tanks
Estimated initial cost: $50,000 depending on treatment objectives
Operation and maintenance: high

Advantages
- Strong-base anion exchange resin can recover nitrate from drainage for reuse
- Recoverable N estimated to be 50 to 100 lb/ac-yr)
- Proven technology but needs to be evaluated for specific case of tile drain systems
- Pre-engineered systems may be purchased

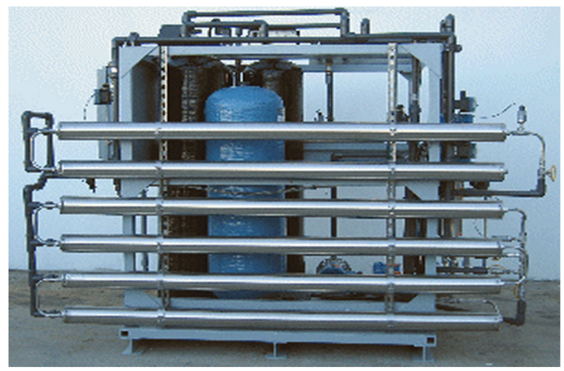
Disadvantages
- Requires onsite power, controls, housing
- Design will depend on site specific water quality characteristics.
- Nitrogen will be mixed with high concentration of NaCl used during regeneration (KCl may be an alternative). Alternately, post treatment by cation exchanger could be used to isolate nitrate.
- Estimated resin needs are 0.2 m^3/d per 100 ac (at 20 gal/min and 100 mg NO_3-N/L)
- Presence of sulfate, other chemicals may interfere and result in increased resin exchange capacity use
- Higher O&M cost for exchange capacity but may be automated.
- Requires relatively high level of process monitoring

REVERSE OSMOSIS

In the reverse osmosis (RO) process, ions are separated from water using a dense membrane. The separated ions are known as the concentrate or brine. The process effluent is purified, demineralized water suitable to reuse. In the case of tile drain water, the concentrate would consist of highly concentrated nitrate, which could be recovered. The RO system can be used to treat a portion of effluent to a high quality, which is then blended with raw effluent to discharge to the environment at the locally required water quality level. Views on a reverse osmosis process are shown on Fig. 7.



(a)



(b)

Figure 7
Views of reverse osmosis process (a) process flow diagram, Crittenden et al., 2007 and (b) industrial application, www.remco.com

Process Notes
Type: Physical separation
Estimated footprint: ~ 100 ft^2 not including process tanks.
Estimated initial cost: $75,000, but depends on pretreatment needs
Operation and maintenance: high

Advantages
· Smallest footprint
· Can recover nutrients and chemicals from drainage for reuse
· Recoverable N estimated to be 50 to 100 lb/ac
· Proven technology but needs to be evaluated for specific case of tile drain systems
· Effective for managing all constituents in drain water
· Pre-engineered systems may be purchased

Disadvantages
· Requires onsite power, controls, housing
· Higher cost, O&M, etc.
· Requires relatively high level of process monitoring