On-site Wastewater Management Training Course

Nutrients and Effluent Dispersal (Land Application Systems)

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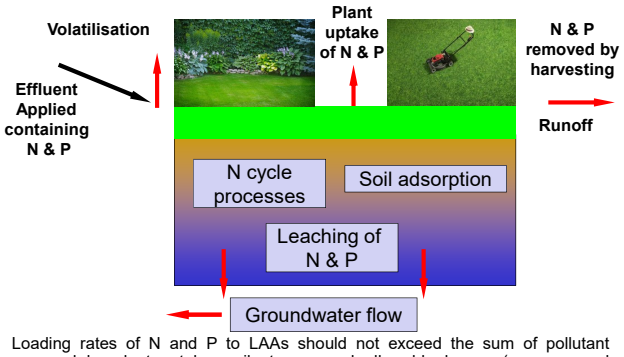
Effluent Application Nutrient Balance



Loading rates of N and P to LAAs should not exceed the sum of pollutant removed by plant uptake, soil storage and allowable losses (gaseous and leaching) for a sustainable system.

Land Application Area

- According to AS/NZS1547:2012 minimum LAA for secondary quality effluent calculated based on following equation:

$$A = Q/DIR$$

where: A = irrigation area (m^2), Q = design daily flow (L/day), DIR = design irrigation rate (mm/day) based on soil hydraulic conductivity and method of irrigation (spray, drip, LPED)

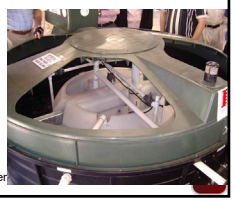
- Example: Daily hydraulic load reticulated water supply with water reduction fixtures 4 br (5 EP × 150 L/p/d) = 750 L/d (Table 4.3)
- Assume Soil Category is 6 - design irrigation rate (DIR) 2 mm/day (Table 4.8) Victorian Guideline (2024)
- LAA for irrigation from treatment system is therefore 375 m^2

ST/ AWTS → LAA 375 m^2

- **Is this calculated area able to accommodate nutrient loads or should a nutrient balance be required?**

Small Treatment Systems

- Few domestic systems approved for N-removal using nitrification/denitrification - some overall net reduction of N may be achieved however
- Few domestic systems designed to reduce P levels using either natural or imported materials rich in iron and aluminium oxides to bind P
- Difficult to achieve without the use of chemicals or adsorptive media which have a finite lifetime & can be expensive



Nutrient Removal Requirements

- AS/NZS1547:2012 (Appendix S) does not provide real guidance in this area but it does acknowledge that nutrients may be an issue in certain situations
- NSW Guideline (2025) requires LAA calculation to determine minimum application area to sustainably assimilate nutrients in soil & vegetation (plant uptake) i.e. determine whatever is most limiting - hydraulic, N or P
- VIC LCA Framework (2014) gives sole consideration to N and does not consider P, although Guideline (2024) recommends it for environmentally sensitive sites
- Other state codes e.g. TAS (Director's Requirements) make no mention of nutrients in assessing LLA

Nutrient Contributions from Typical Residential Dwellings

Nutrient	Mass Loading (g/p/d)	Typical Concentration Untreated (mg/L)	Typical Concentration Treated (mg/L)
Total Nitrogen	6 - 17	30 - 85	15 - 75
Ammonia	1 - 3	4 - 13	negligible
Nitrite and Nitrate	< 1	<1	15 - 45
Total Phosphorus	12	4 - 15	4 - 10

Source: Appendix S AS/NZS1547:2012

What Happens to N in Effluent?

- Mineralisation of organic N results in formation of nitrate
- Some volatilisation of ammonia but any losses small and variable
- Nitrification of ammonia to nitrate in aerobic areas
- Can be taken up by vegetation in inorganic form (major)
- Some lost back to atmosphere through denitrification as gas (minor)
- Mass load of N in effluent is often surplus and not utilized; leaching to groundwater likely as there is usually sufficient to meet vegetative requirements

Design Solutions

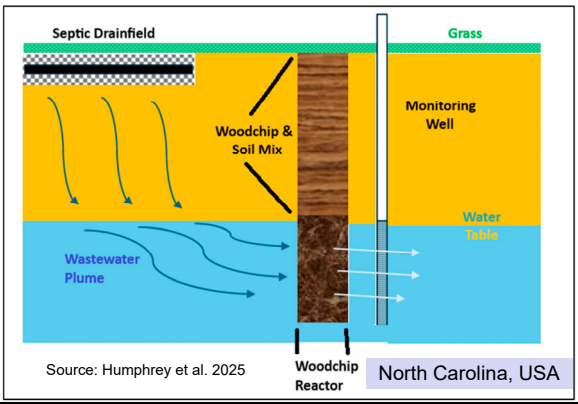
- May be required in situations with high nitrate loads in wastewaters and sensitive sites e.g. sandy soils with high watertables
- Can be used to remediate groundwater as well
- For denitrification to occur, a carbon source is essential & there must be limited available oxygen – microorganisms strip oxygen off nitrate to oxidise C
- Sealed passive systems typically use woodchips/sawdust as C source and nitrified effluent is flooded into system. Examples are:

- Field Denitrification Beds
- Woodchip Denitrification Walls (PRBs)

Field Denitrification Bed

Lake Taupo, NZ

Permeable Reactive Barrier

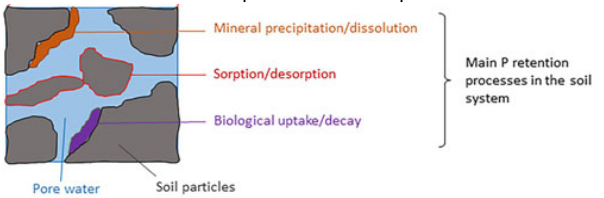


Source: Humphrey et al. 2025

North Carolina, USA

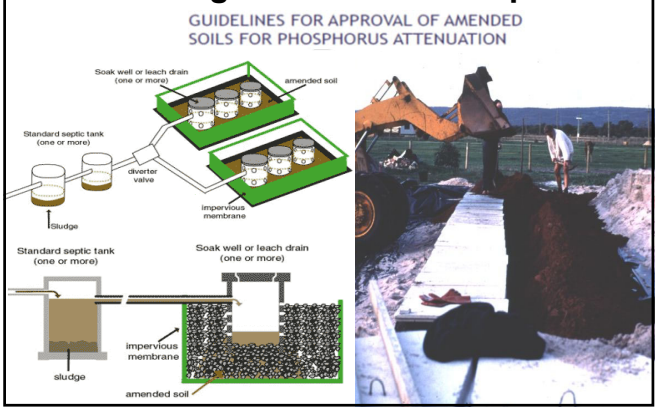
What Happens to P in Effluent?

- Taken up in vegetation in inorganic form (minor), plants uptake 8-10 times less P than N
- Adsorbed or immobilized in soil (major) - hydrous oxides of Fe and Al can bind P – quantified in laboratory test;
- Sustainable life of LAA depends on P adsorption of soil



- Leaching will only occur when adsorption sites saturated & additions are in excess of vegetation requirements

Amending Soils for P Adsorption



Mass Balances

In accounting for **material** (nutrients) entering and leaving a system, **mass** flows need to be identified … but this is not always easy to do!

Land Use Activity	Nitrogen	Phosphorus
Piggeries	8	2.7
Dairy Shed Effluent	5.4	0.7
Septic Tanks	4	0.3 - 0.7

Units: kg/person or animal/yr

Land application of super!

Mass Balance Approach

- N production from septic tanks approx. 4 kg/p/yr
- P production from septic tanks range 0.3 – 0.7 kg/p/yr – use 0.5
- Calculation based use of above rates and number in household - assume 5 EP
- Calculated N from household - 20 kgN/yr
- Calculated P from household - 2.5 kgP/yr
- Need to know whether N and P loads can be assimilated within area calculated based on hydraulic load – "sustainable?"
- Now…….. Start here!

Mass Balance Approach

- Using previous example from secondary treated effluent (ATS) 375 m^2 is required for effluent irrigation
- This is equivalent to an areal loading rate of: 533 kg N/ha/yr and 67 kg P/ha/yr

Plant Nutrient Uptake

Crop	TN (kg/ha/yr)	TP (kg/ha/yr)
Eucalypts	**180**	**20**
Pines	**350**	**35**
Improved Pasture	**300**	**30**
Lawn - Fully managed with clippings removed	**240**	**30**

- **Relying on Lawn for nutrient uptake, TN (533>240 kg/ha/yr) & TP (67>30 kg/ha/yr) generated from this domestic system cannot all be removed by plants!**

Simple Example of N Balance

- 1. Determine the daily N load
  - Assume Total Nitrogen (TN) effluent concentration:
  - 50 mg/L assumed following secondary treatment
  - Daily hydraulic load: 750 L/day
  - Daily N load: 50 mg/L x 750 L/day = 37,500 mg/day
- 2. Determine the annual N load
  - 37,500 mg/day x 365 days/year = 13,687,500 mg/year
  - Annual N load = 13.69 kg/year
- 3. Allow 20% loss through denitrification, volatilization, microbial digestion and other processes
  - 13.69 kg/year x 0.8 = 10.95 kg/year which is annual N load to LAA

Modified from approach in VIC LCA Assessment Framework 2014

Simple Example of N Balance

- 4. Allow for N uptake by plants using fully managed lawn of 240 kg/ha/year
  - Divide the annual N load by the N uptake rate
  - 10.95 kg/year ÷ 240 kg/ha/year = 0.0456 ha
  - multiply by 10,000 m^2/ha = 456 m^2
  - Minimum area required for N uptake = 456 m^2

Required LAA for N is larger than the area required for the hydraulic load (375 m^2). Land area for assimilation of N could be reduced by changing various assumptions e.g. lower N conc. and/or reducing volume of wastewater generated, but what about TP minimum area?

Phosphorus

- With respect to nutrients, MAV (2014) LCA document gives sole consideration to nitrogen! (Section 4.6.7 Nutrient Balance, p33)
- Victorian Guideline (2024) p41 states that " Water & nutrient balance modelling is recommended for environmentally sensitive sites including:
  - ➢ sandy soils – nutrient balance to be considered particularly for environmentally sensitive sites (for example, special water supply catchment or high-quality groundwater)
  - ➢ heavy clay soils – a water balance may indicate that a reduced application rate is required to prevent waterlogging and runoff
  - ➢ sites with high rainfall (>900 mm annual average) – a water balance may indicate the need for a larger application area to manage wet weather
  - ➢ land application systems not covered by AS/NZS 1547:2012

Review

- Significant work is required to undertake nutrient balances for OWMS (particularly P) & any important assumptions need to be clearly outlined
- Nutrient assimilation can be particularly important in environmentally sensitive sites/locations & conservative approach recommended
- Overall contribution of OWMS to nutrient loads at catchment scale can be minor

Source	Total P (kg)	Total N (kg)	*E.coli* (cfu/100mL)
On-Site Systems	21.68 (1.77%)	125.5 (0.59%)	4.15×10^{11} (0.08%)
Other Sources	1206 (98.23%)	21231 (99.41%)	1.54×10^{14} (99.92%)

Further Reading

- Burberry, L *et al*., (2020), Woodchip Denitrification Wall Technology Trialled in a Shallow Alluvial Gravel Aquifer, *Ecological Engineering*,157, 105996, https://doi.org/10.1016/j.ecoleng.2020.10599
- EPA Victoria Guideline for onsite wastewater management (2024)
- Gardner, T., Geary, P., & Gordon, I. (1997), Ecological Sustainability and On-site Effluent Treatment Systems, *Australian Journal of Environmental Management*, *4*(2), 144-156, https://doi.org/10.1080/14486563.1997.10648378
- Humphrey Jr., C.P.; Iverson, G.; O'Driscoll, M. (2025), Performance Assessment of a Permeable Reactive Barrier on Reducing Groundwater Transport of Nitrate from an Onsite Wastewater Treatment System, *Hydrology,* 12, 18. https://doi.org/10.3390/ hydrology1201001
- MAV Victorian Land Capability Assessment Framework (2014)

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