On-site Wastewater Management Training Course

Nutrients and Land Application Areas

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Nutrient Reduction - Small Treatment Systems

- Difficult to consistently achieve despite claims made by manufacturers
- Few domestic systems approved as Nitrogen-removing systems using nitrification/denitrification processes - some overall net reduction of N may be achieved
- Some domestic systems designed to reduce Phosphorus 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

Nutrient Removal in LAAs

- Reliance on LAAs to receive, treat and absorb (manage) some effluent and nutrients evenly with landscaping to utilise nutrients in effluent by plant uptake
- AS/NZS1547:2012 does not provide real guidance in this area (other than acknowledge there may be situations where nutrients may be an issue)
- NSW Guideline requires LAA calculation based on which is most limiting (hydraulic, N or P loading)
- VIC Code gives sole consideration to N
- Most other state codes such as TAS (Director's Requirements) make no mention of nutrients

AS/NZS1547:2012 (Appendix S)

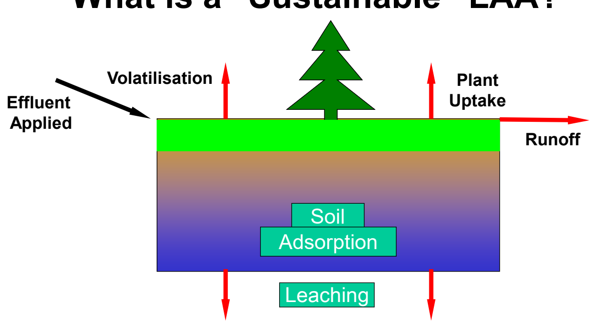
Standard design is based primarily on hydraulic loading. There is no guidance on how to use nutrient data or how to apply in the design and sizing of LAAs.

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: AS/NZS1547:2012 from USEPA

What is a "Sustainable" LAA?



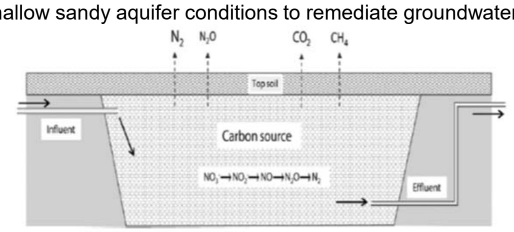
Loading rates of N and P to LAAs should not exceed the sum of pollutant removed by plant uptake, soil storage and allowable losses (gaseous and leaching). Nutrients need to be assimilated on-site

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

Field Denitrification Beds

- Can be used in situations where there are high nitrate loads in wastewaters; HRT is important
- For denitrification to occur a carbon source is essential – microorganisms strip oxygen off nitrate to oxidise carbon
- Example of sealed system using woodchips/sawdust as C source – nitrified effluent flooded into system
- Woodchip denitrification walls can also be used subsurface in shallow sandy aquifer conditions to remediate groundwaters



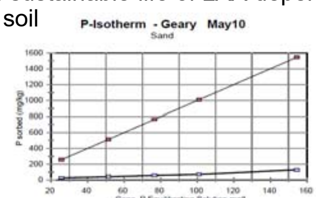
Field Denitrification Beds

What Happens to P in Effluent?

- Taken up in vegetation uptake in inorganic form (minor), plants uptake 8-10 times less P than N
- Many soils good at immobilising P - major mechanism of P removal is therefore soil adsorption
- P can be chemically precipitated and adsorbed in soils (major, particularly in clay soils)
- Leaching will only occur when adsorption sites saturated (if soil sorption capacity exceeded) and additions are in excess of vegetation requirements
- More of an issue in specific (sandy) soils and sensitive in locations (e.g. Category 1 and 2 soils)

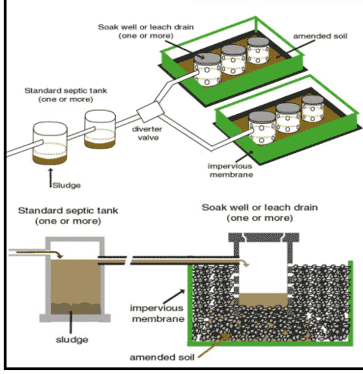
P Adsorption

- Many soils good at immobilising P – (major mechanism) - depends on presence of hydrous oxides of Fe and Al
- Adsorption rates of P may range between 0 – >1,000 mg/kg of soil - measured in laboratory test - indices used include Phosphate Retention Index (PRI) and Phosphate Sorption Index (PSI)
- Calculation of sustainable life of LAA depends on P adsorption of soil



Amending Soils for P Adsorption

GUIDELINES FOR APPROVAL OF AMENDED SOILS FOR PHOSPHORUS ATTENUATION



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 (m²), Q = design daily flow (L/day), DIR = design irrigation rate (mm/day) based on soil hydraulic conductivity and method of irrigation (spray, drip, LPED)

- Assume hydraulic load for a 5-person household is 750 L/day; Assume Category 6 soil - design irrigation rate (DIR) is 2 mm/day
- 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?**

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!

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Mass Balance Approach

- P Production from septic tanks range 0.3 – 0.7 kg/p/yr – use 0.5
- N Production from septic tanks approx. 4 kg/p/yr
- Calculation based use of above rates and number in household - assume 5 people
- 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
- 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: 530 kg N/ha/yr and 67 kg P/ha/yr
- A "sustainable" LAA needs to show whether the N and P can be assimilated on this land area!

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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**

- AS/NZS1547 states that P requirements for pasture 3-22.5 kgP/ha/y – higher levels if renovating pasture on old land
- AS/NZS1547 states that immature forests can remove between 50 - 90 kgN/ha/y

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Simple Example of N Balance

- 1. Determine the daily N load

  Assume Total Nitrogen (TN) effluent concentration:

  75 mg/L determined from ST production (4 kgN/p/yr from mass balance estimate)

  Daily hydraulic load: 750 L/day

  Daily N load: 75 mg/L x 750 L/day = 56,250 mg/day
- 2. Determine the annual N load

  56,250 mg/day x 365 days/year = 20,531,250 mg/year

  Annual N load = 20.53 kg/year
- 3. Allow 20% loss through denitrification, volatilization, microbial digestion and other processes

  20.53 kg/year x 0.8 = 16.42 kg/year which is annual N load

Modified from approach in VIC LCA Assessment Framework 2014

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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

  16.42 kg/year ÷ 240 kg/ha/year = 0.0684 ha

  multiply by 10,000 m^2/ha = 684 m^2

  Minimum area required for N uptake = 684 m^2

Required LAA for N is substantially larger than the area required for the hydraulic load. 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?

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Simple Example of P Balance

(using N approach on previous slides)

- With daily hydraulic load of 750 L/d and TP concentration of 9 mg/L, annual load to LAA is 2.46 kg/yr (close to mass balance estimate of 2.5 kg/yr)
- Allow for P uptake by fully managed lawn of 30 kg/ha/yr
- Divide annual P load by the P uptake rate to calculate LAA: 2.46 kg/year ÷ 30 kg/ha/year = 0.0820 ha

  multiply by 10,000 m^2/ha = 820 m^2
- Minimum area required for P uptake = 820 m^2
- While assimilation of P requires much larger land area than either hydraulic load or N, soil adsorption of P has not yet been considered

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To Include Soil P Adsorption Data

- Calculation uses assumed P adsorption of soil (500 mg/kg) and soil bulk density 1.5 g/cm^3 (1,500 kg/m^3); also assume that soil is 0.6 m deep
- Convert P_{sorb} in mg/kg to kg/ha:

P_{sorb} (kg/ha) = P_{sorb} (mg/kg) × soil depth (m) × BD (kg/m^3) × 0.01

- By substitution then:
  P_{sorb} (kg/ha) = 500 × 0.6 × 1,500 × 0.01 = 4,500 kg/ha

- LAA area just required for hydraulic load - 375 m^2
- P_{sorb} of 375 m^2 LAA is 4,500 × 0.0375 = 168.7 kg
- Assuming LAA life of 25 years, P load generated by system is 2.46 kg/yr × 25 yr which is 61.5 kg (<< than P_{sorb} of 168.7 kg)
- LAA will theoretically accommodate P generated by system just by soil adsorption (without considering any P uptake by plants)

Critical Loading Rate Concept

- NSW Guideline (Appendix 6) adopts approach using concept of critical loading rate L_x
- Based on the assumed ability of vegetation to use nutrients before they pass through the root zone (very conservative)
- Guideline requires calculations to be undertaken to determine irrigation area requirements for N & P with the larger area chosen as minimum area

- Use formula A = (C × Q)/L_x

- where A = land area (m^2); C = conc. of nutrient (mg/L); Q = design daily flow (L/d) and L_x = critical loading rate of nutrient (mg/m^2/d)

Critical Loading Rate Concept

- Recommended critical loading rates in NSW Guideline: L_x for nitrogen for pasture L_n – 18 - 36 mg/m^2/d (equivalent to 66 - 131 kg/ha/yr) and L_x for phosphorus for pasture L_p – 2 - 4 mg/m^2/d (equivalent to 7 - 14 kg/ha/yr)

The use of these low loading rates results in unrealistically large land areas for nutrient assimilation, significant cost to install and the striped lawn effect!
Nutrient balance approach and P_{sorb} values in NSW Guideline should not be used.

Annual Pollutant Loads from a Small Catchment

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%)