On-site Wastewater Management Training Course

Nutrients and Effluent Application Areas (EEA)

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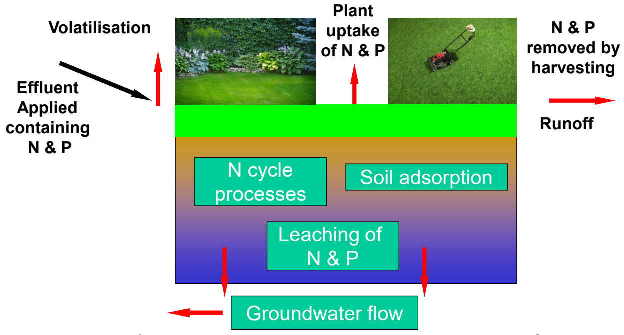
Effluent Application Nutrient Balance



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

Effluent Application Area

- According to AS/NZS1547:2012 & NSW Guideline, minimum EAA can be calculated based on following equation:
-

$$A = Q \div (DIR \text{ or } DLR)$$

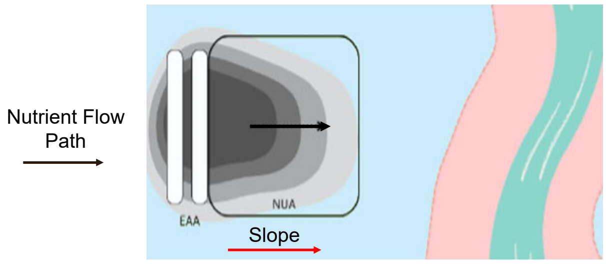
where: A = area (m²), Q = daily hydraulic load (L/day), DIR or DLR = design irrigation rate or design loading rate (mm/day) based on soil hydraulic conductivity and method of irrigation (spray, drip, LPED)

- Assume hydraulic load for a 5 EP 3 br household is 750 L/day; Assume Category 6 soil - design irrigation rate (DIR) is 2 mm/day
- Land area requirement for irrigation from treatment system is therefore 375 m^2

ST/ AWTS ⟶ EAA 375 m^2

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

Transport of Nutrients - Schematic

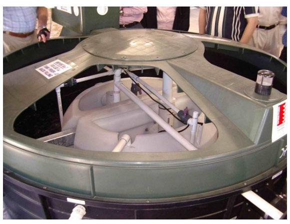


NUA - Nutrient Uptake Area is land area set aside for further nutrient reduction downslope from an EEA system

NUA = Nutrient Balance Area Requirement – Hydraulic Area Requirement

Small Treatment Systems

- Few domestic systems approved for N-removal using nitrification/denitrification processes - 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 requires EAA 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 loading
- VIC Code gives sole consideration to N and does not consider P
- Most other state codes such as TAS (Director's Requirements) make no mention of nutrients in assessing land application area

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 (<u>major</u>)
- Some lost back to atmosphere through denitrification as gas (<u>minor</u>)
- Mass load of N in effluent is often <u>surplus</u> and not utilized; leaching to groundwater likely as there is usually sufficient to meet vegetative requirements

Design Solutions

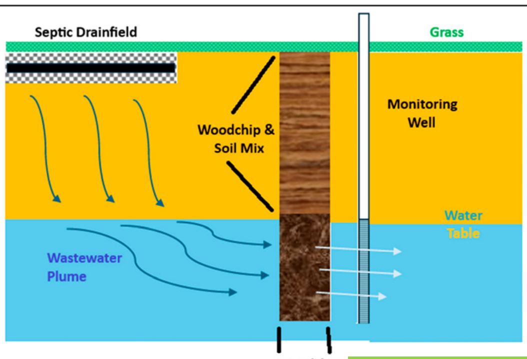
- May be required in situations with high nitrate loads in wastewaters and sensitive sites e.g. sandy soils with high watertables
- Can be used to remediate groundwater as well
- For denitrification to occur, a carbon source is essential & there must be limited available oxygen – microorganisms strip 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:

- <u>Field Denitrification Beds</u>
- <u>Woodchip Denitrification Walls (PRBs)</u>

Field Denitrification Bed

Lake Taupo, NZ

Permeable Reactive Barrier

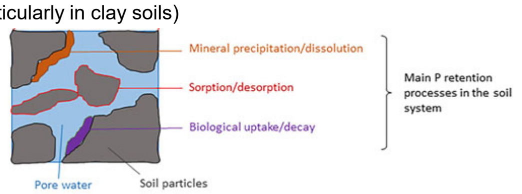


Source: Humphrey et al, 2025

North Carolina, USA

What Happens to P in Effluent?

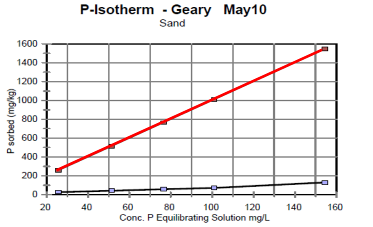
- Taken up in vegetation uptake in inorganic form (minor), plants uptake 8-10 times less P than N
- Many soils good at immobilising P - major mechanism of P removal is therefore soil adsorption
- P can be chemically precipitated and <u>adsorbed</u> in soils (<u>major</u>, particularly in clay soils)



- Leaching will only occur when adsorption sites saturated & additions are in excess of vegetation requirements (an issue in sandy soils and sensitive locations)

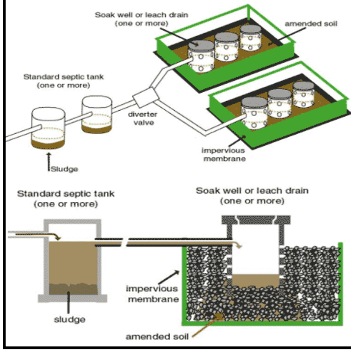
P Adsorption

- Many Australian soils are good at immobilising (binding) P, particularly due to presence of hydrous oxides of Fe and Al. Adsorption testing attempts to quantify soil's ability to bind P but makes no allowance for organic P in soil
- 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)
- Sustainable life of EAA depends on P adsorption of soil
- Guideline contains typical P sorption values for different soil textures



Amending Soils for P Adsorption

GUIDELINES FOR APPROVAL OF AMENDED SOILS FOR PHOSPHORUS ATTENUATION



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

- 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 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 determined from Secondary Treatment*
  - Daily hydraulic load 5 EP (3 brm): 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 land application area

- **Higher end Secondary Treated Effluent range NSW Guideline**

Simple Example of N Balance

- <u>4. Allow for N uptake by plants using fully managed lawn of 240 kg/ha/year</u>

  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

  <u>Minimum area required for N uptake = 456 m^2</u>

Required land area for N is still larger than the area required for the hydraulic load (375 m^2).

NUA = Nutrient Balance Area Requirement – Hydraulic Area Requirement
NUA = 456 – 375 = 81 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?

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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 10* mg/L, <u>annual load to LAA is 2.74 kg</u>
- Allow for P uptake by fully managed lawn of 30 kg/ha/yr
- Divide annual P load by the P uptake rate to calculate area required:

  2.74 kg/year ÷ 30 kg/ha/year = 0.0913 ha

  multiply by 10,000 m^2/ha = 913 m^2
- <u>Minimum area required for P uptake = 913 m^2</u>

- While assimilation of P requires much larger land area than either hydraulic load or N, <u>the importance of soil P adsorption has not yet been considered</u>

- **Lower end Secondary Treated Effluent range NSW Guideline**

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To Include Soil P Adsorption Data

- Calculation uses measured P adsorption of soil (500 mg/kg) & soil bulk density 1.5 g/cm^3 (1,500 kg/m^3); also assume that soil adsorption is within top 0.8 m soil,
- 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, soil can "potentially" adsorb:
- P_{sorb} (kg/ha) = 500 × 0.8 × 1,500 × 0.01 = <u>6,000 kg/ha*</u>

- *The "potential" soil P adsorption is sometimes discounted because assumed that not all the available soil volume can be accessed by the effluent applied (discount factors used between 0.25 & 0.75)
- For this calculation assume 0.50 (NSW Guideline)

- Therefore……. P_{sorb} = <u>3000 kg/ha</u>

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Irrigation Area for Phosphorus

- Now use equation - Irrigation Area = P_{gen} ÷ (P_{sorb} + P_{plant})

- Assume area required to contain P for 50 years
- Total P load to LAA for 50 yrs is 2.74 kg/yr × 50 yr = 137 kg
- Annual plant uptake for 50 yrs is 30 kg/ha/yr × 50 yr = 1500 kg/ha
- "Potential" soil P adsorption = 3000 kg/ha

- Total P capacity 50 yrs = Soil P adsorption + P plant uptake
  = 3000 + 1500 = 4500 kg/ha

- Therefore, Irrigation Area = Total P Load for 50 yrs (kg) ÷ Total P capacity for 50 yrs (kg/ha)
  = 137 kg ÷ 4500 kg/ha
  = 0.0304 ha = <u>304 m^2</u>
- Now soil P adsorption has been considered, irrigation area to accommodate P is less than that already calculated for hydraulic load <u>(375 m^2) & for N (456 m^2)</u>

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Review

- Significant work is required to undertake nutrient balances for OWMS & several important assumptions need to be clearly outlined
- Nutrient assimilation can be particularly important in environmentally sensitive sites/locations but at other sites relatively insignificant
- Overall contribution of OWMS to nutrient loads in catchments can be small

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 <u>(98.23%)</u>	21231 <u>(99.41%)</u>	1.54 × 10^{14} <u>(99.92%)</u>

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
- 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
- Patterson, R. (2016), Calculations for Phosphorus Management in Wastewater, Technical Note: T16-1, Lanfax Laboratories, Armidale NSW. https://www.lanfaxlabs.com/soil_phosphorus.htm

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