Private Sewage Systems & Planning Policy

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Talk outline

1. **Project overview**
2. **Policy : The 125% rule**
3. **Is there variation in the concentration and composition of phosphorus compounds found in private sewage systems?**
4. **Is there variation in behaviour of private sewage system users?**
5. **Does user behaviour impact the type of phosphorus compounds found in private sewage systems?**

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Photo - Heather Lowther, CEH

Project team

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PhD project overview

Does human behaviour and personality type affect the quantity and composition of phosphorus we produce

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PhD project overview

Photo: iStockPhoto

Does human behaviour and personality type affect the quantity and composition of phosphorus we produce

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Experimental unit

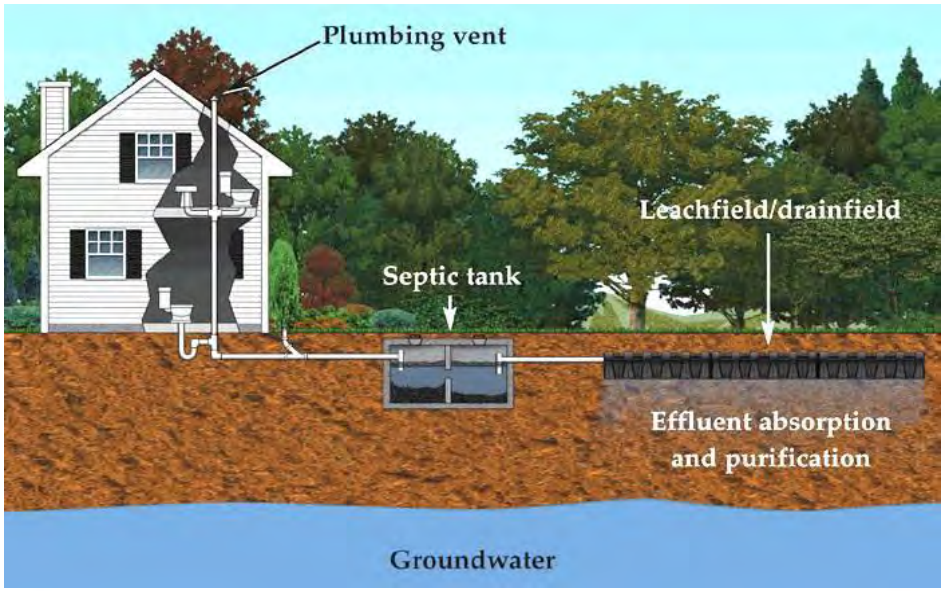

Image courtesy of www.thenaturalhome.com

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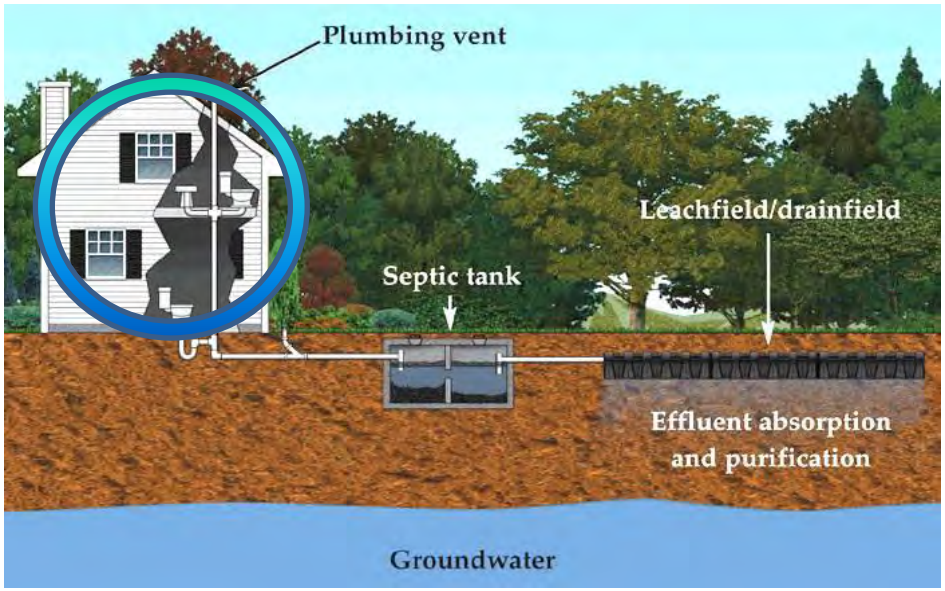

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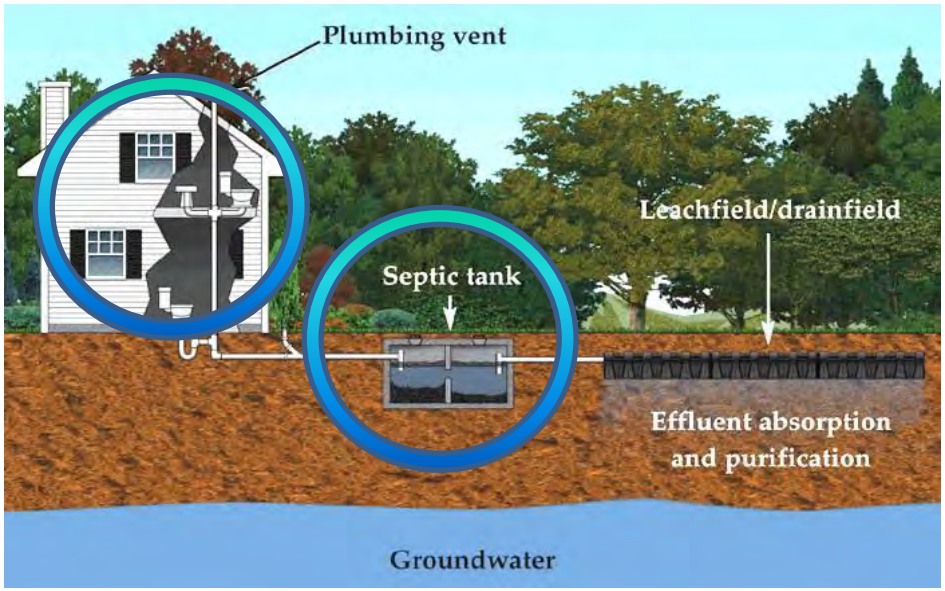

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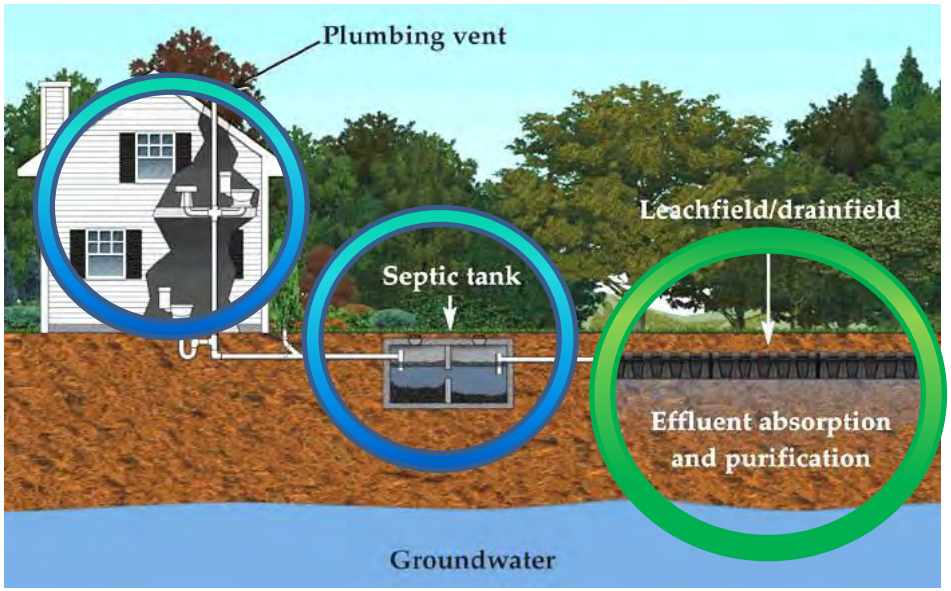

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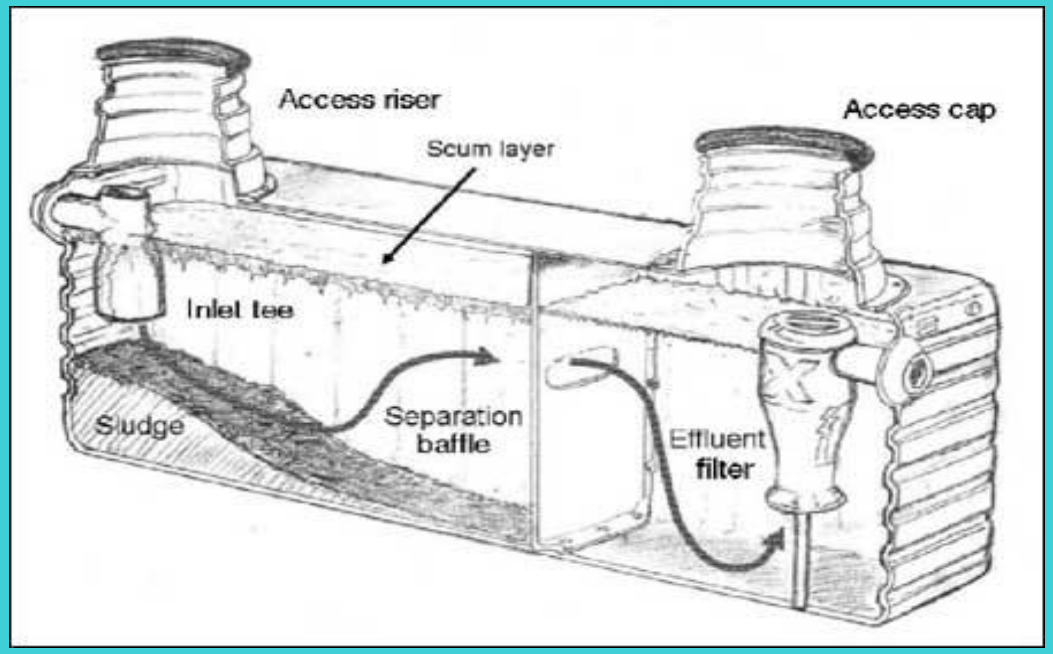
Private sewage systems



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Data collected

- Four month sampling regime of 7 septic tanks for P concentration (colorimetric analysis)
- Questionnaires to every address in the Loch Leven catchment with a PSS (23% return n=158)
- Further sampling of a brave subset of PSS users (n=12)
  - Colorimetric analysis of P – concentration of P
  - NMR analysis of P – composition of P
  - Questionnaire to assess internal and external personality characteristics

Talk outline

1. Overview of this project

2. Overview of the 125% rule

3. Is there variation in the concentration and composition of phosphorus compounds found in private sewage systems

4. Is there variation in behaviour of private sewage system users

5. Does user behaviour impact the type of phosphorus compounds found in private sewage systems

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What is the 125% rule ?

- Policy aiming to ensure new developments requiring PSS do not cause a net increase in phosphorus to Loch Leven, achieved by mitigating phosphorus pollution from 3rd party PSS
- Policy 10, 11 and 12 in the Kinross Area Local Plan
- A policy that uses the precautionary principle. The precautionary principle enables rapid response in the face of a possible danger to human, animal or plant health, or to protect the environment. In particular, where scientific data do not permit a complete evaluation of the risk,

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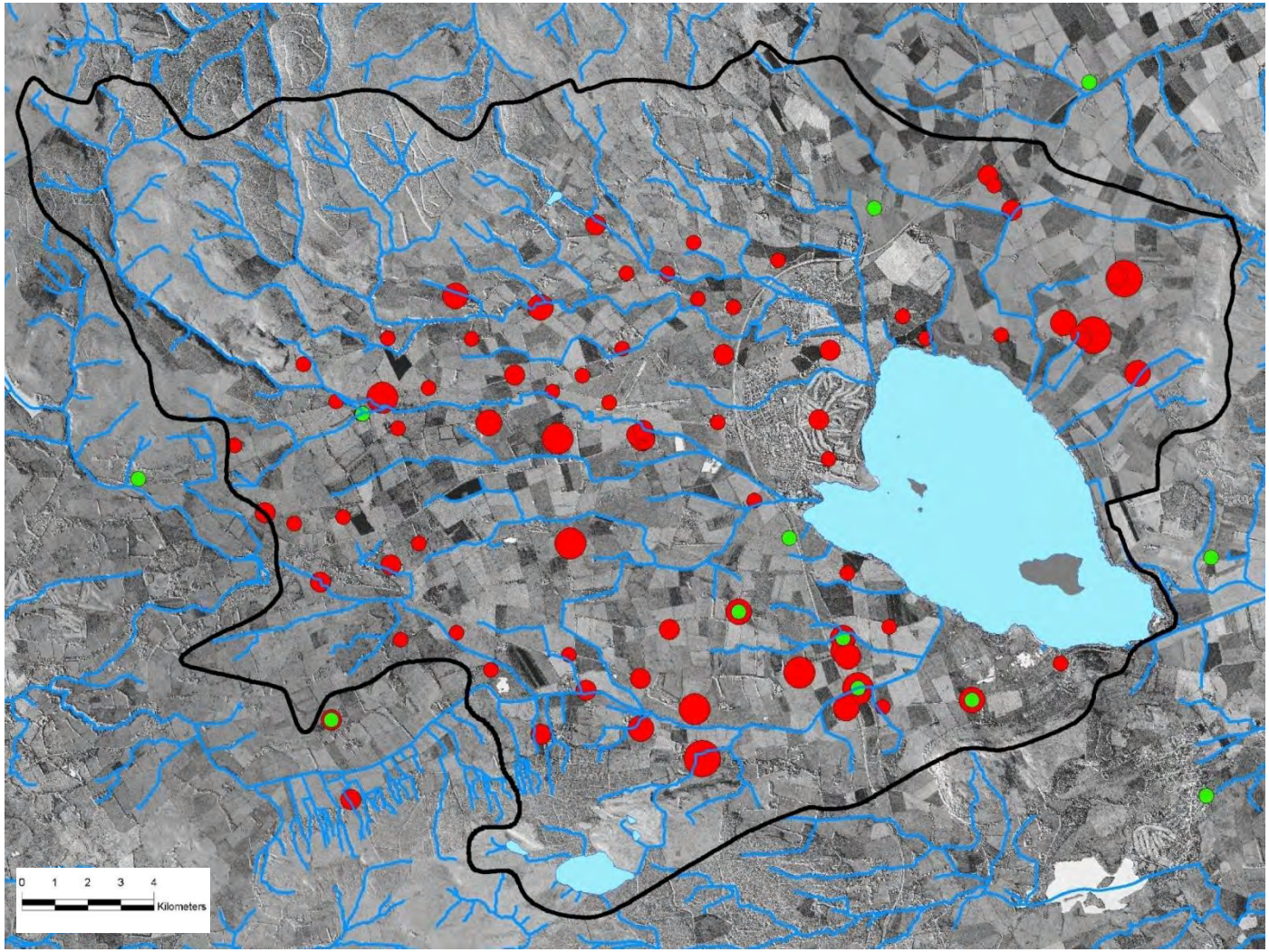
Geese over Loch Leven courtesy of the www.courier.co.uk
Brown Trout courtesy of www.switters.wordpress.com

Water body	Estimated P load from private sewage systems (tonnes yr^{-1})	Proportion of external P load attributable to private sewage systems (%)	Reference
Llyn Tegid, North Wales, UK	4.60	3%	Milliband *et al* (2002)
Lough Conn, West Ireland	1.58	5%	McGarrigle & Champ (1999)
Loch Leven, South East Scotland, UK	1.50	10%	Frost (1996)
Loch Leane, , South Ireland	1.50	12%	KMM & Pettit (2000)
Bassenthwaite Lake, North England, UK	2.30	14%	May *et al* (1996)
Loch Flemington, North Scotland, UK	0.02	18%	May (2001)
Loch Ussie, North Scotland, UK	0.03	22%	May and Gunn (2000)
Black Beck River, into Esthwaite Lake, North England, UK	0.25	40 - 76%	Hall (2001)

Density of properties connected to PSS in the Loch Leven Catchment



Properties not served by mains sewerage (n = 654)

Properties in the with PSS registered with the local authority (n = 21) (provided by SEPA)

Surface water catchment area = 145 km^2

Loch Leven surface area = 13.3 km^2

80% of land use is agricultural

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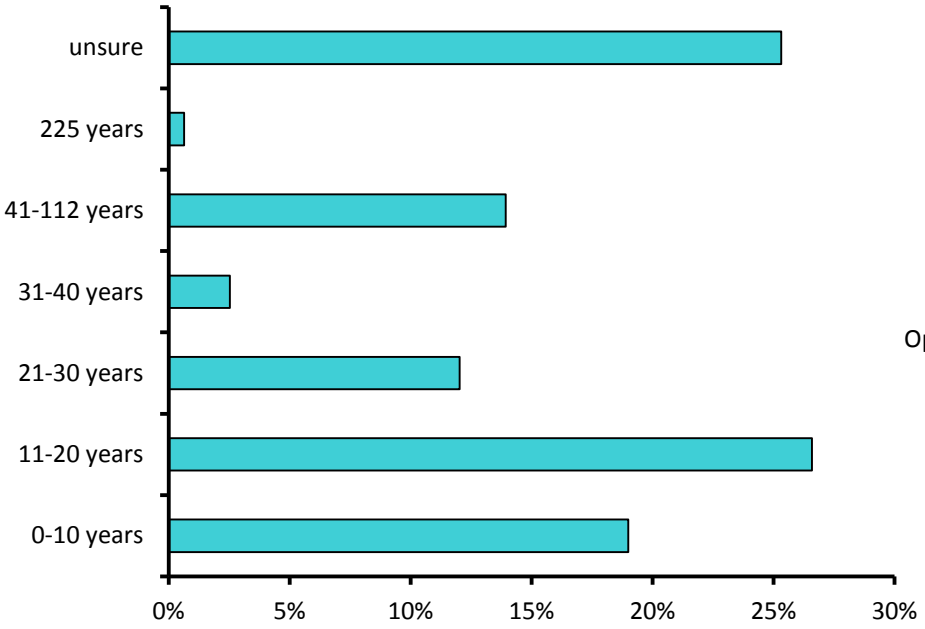
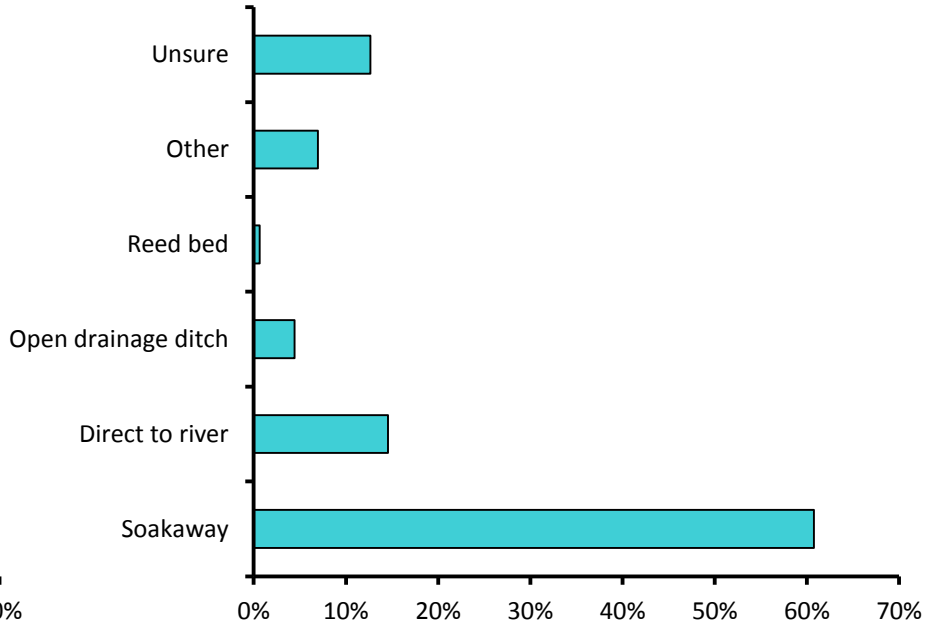
Variation in PSS and user demands

Age of tanks



Post tank delivery



- 43% shared tanks with neighbours
- 50% singular septic tanks
- 7% unsure

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P load discharge =(Daily wastewater per person) x (P.E) x (effluent TP concentration of septic tank)

Assumptions

Waste water produced per person per day = 180 l

People equivalent (P.E) = number of bedrooms + 2

Primary treatment = **10 mg Pl^{-1}**

Secondary treatment = **5 mg Pl^{-1}**

Tertiary treatment = **2 mg Pl^{-1}**

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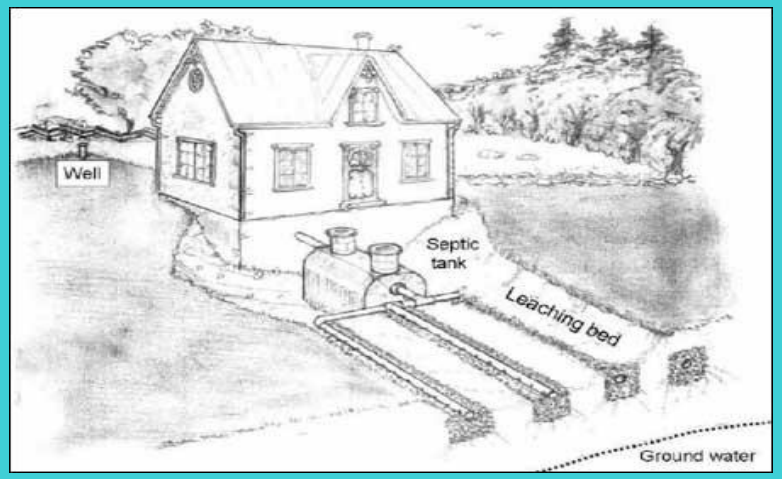
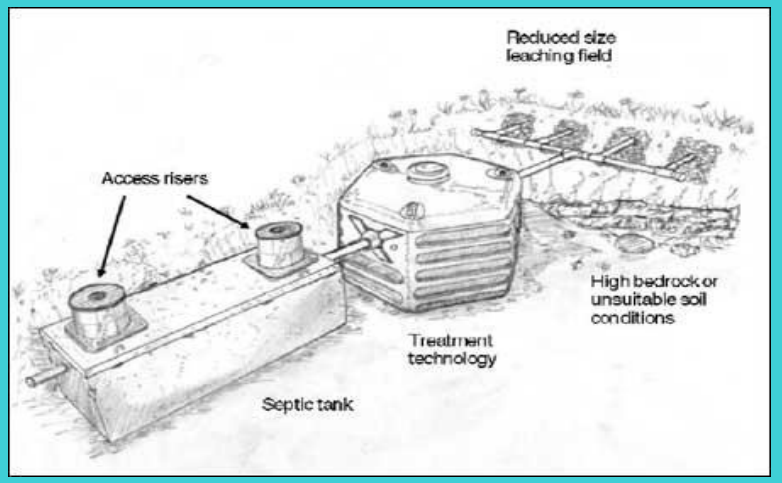
Primary, Secondary and Tertiary Treatment Systems



Credit: Éric Brunet, Ontario Rural Wastewater Centre, University of Guelph
Figure 2: Conventional septic system



Credit: Éric Brunet, Ontario Rural Wastewater Centre, University of Guelph
Figure 5: Alternative treatment technology

- **Primary treatment** = single septic tank
- **Secondary treatment** = wetlands, reed beds and mechanical treatment plants
- **Tertiary treatment** = sand filters, drum filters, membrane systems or chemical dosing

How the 125% rule works

Identify P reductions available via 3rd party improvements

Mitigation: 5-bedroom house with primary treatment -> secondary treatment

Mitigation offered = **6.3 g Pday^{-1}**

Existing discharge with primary treatment = **12.6 g Pday^{-1}**
Discharge after upgrade to secondary treatment **6.3 g Pday^{-1}**

Mitigation = 125% TP budget

TP budget = < 5.04 g Pday^{-1}

Permission not granted if proposed development is > TP budget

Proposed development: 3 bedroom house with secondary treatment installed
Estimated P = **4.5 g Pday^{-1}**

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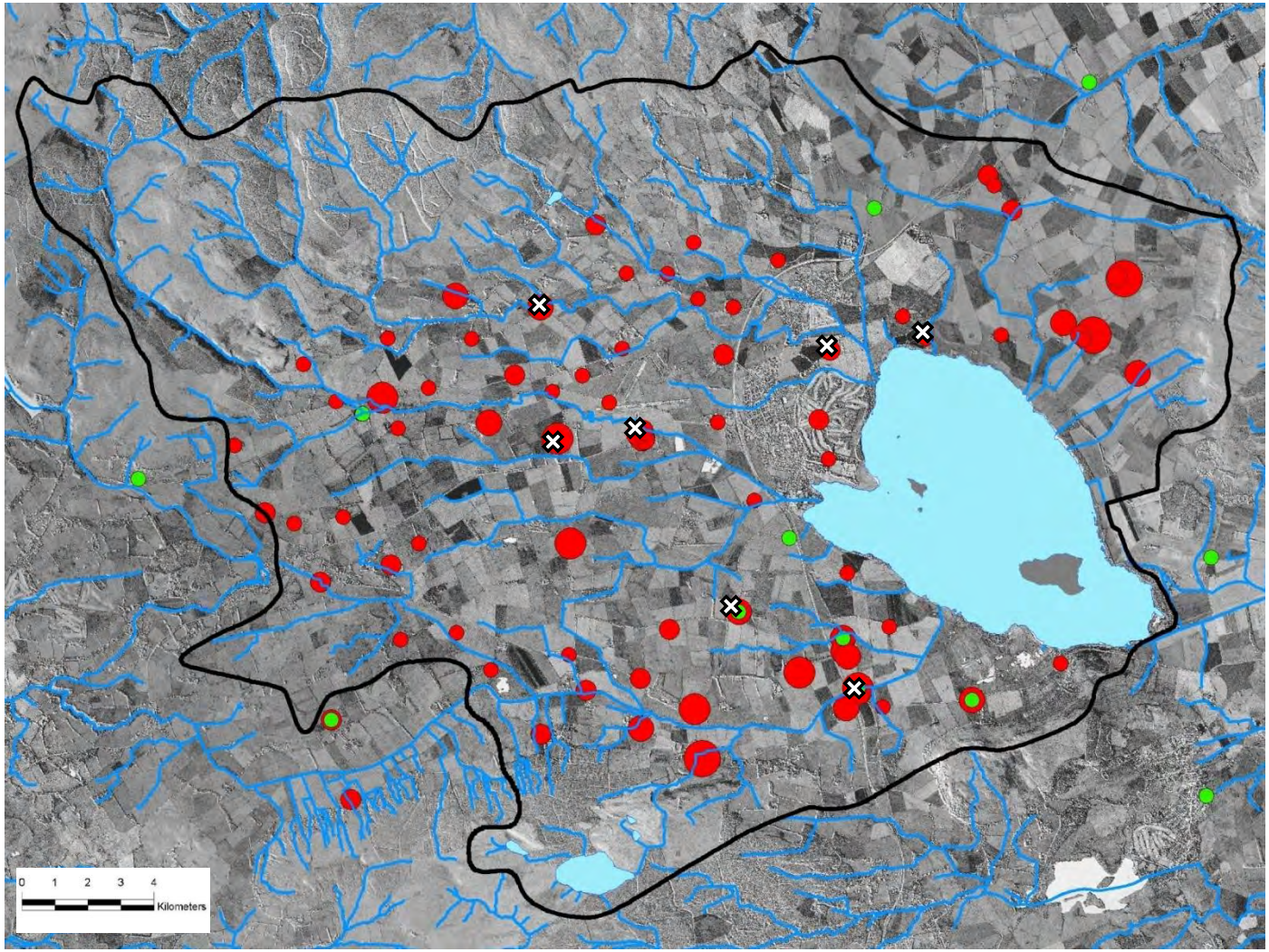
3. Is there variation in the concentration and composition of phosphorus compounds found in private sewage systems

Location of experimental units and method overview



⊠ Experimental units

Samples were assessed for TP, TSP and SRP using colourimetric spectrophotometry

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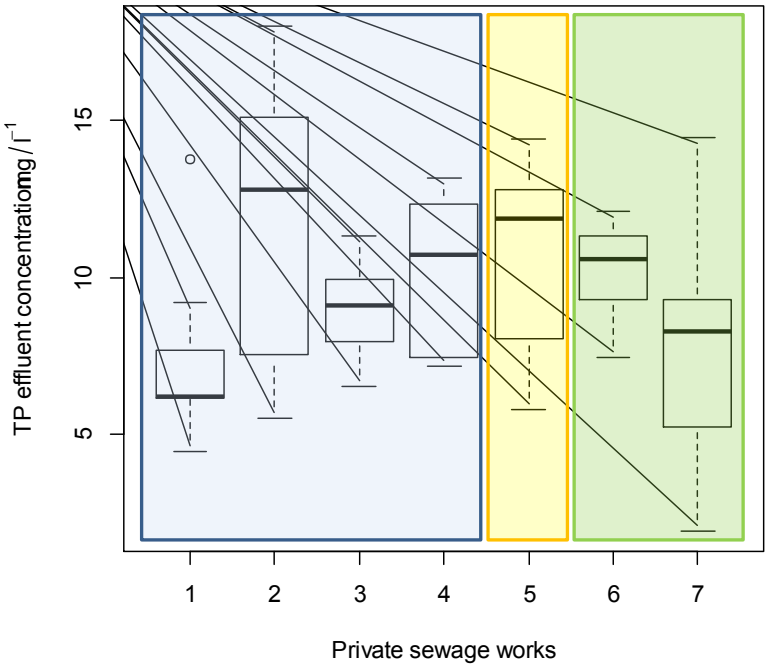
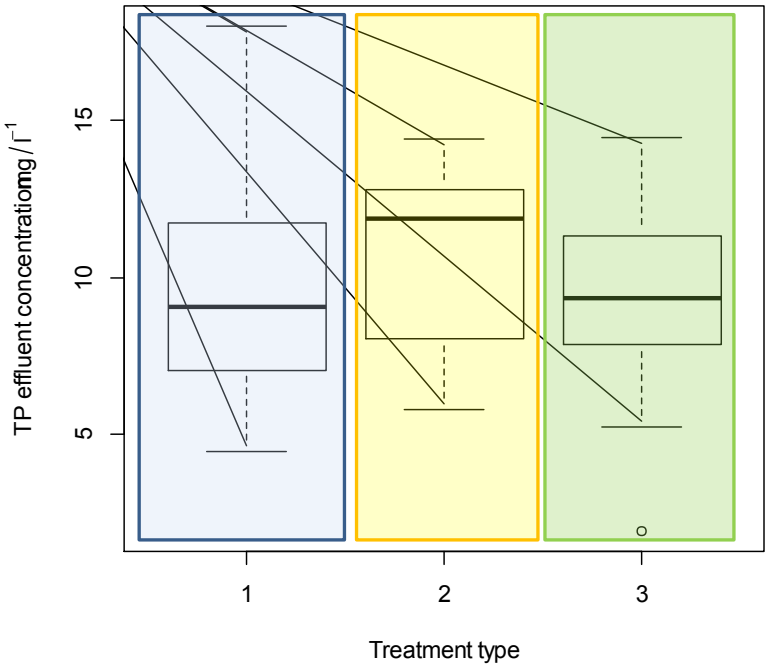
Concentration of TP between PSS and between PSS treatment type

Median = 9.28mgl^{-1} (range = 1.91 – 18.01mgl^{-1})



$F_{(6,40)} = 1.36$, $p = 0.25$, $n = 47$



$F_{(2,44)} = 0.274$, $p = 0.76$, $n = 47$

Primary treatment = 9.06 mg Pl^{-1} (4.45 – 18.01 mgPl^{-1})
Secondary treatment = 11.86 mg Pl^{-1} (5.79 – 14.43 mgPl^{-1})
Tertiary treatment = 9.31 mg Pl^{-1} (1.91 – 14.44 mgPl^{-1})

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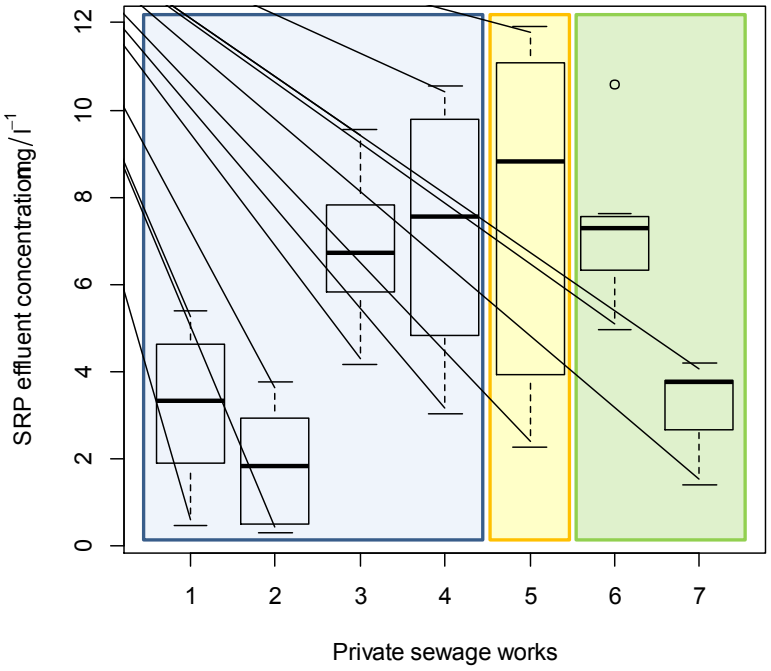
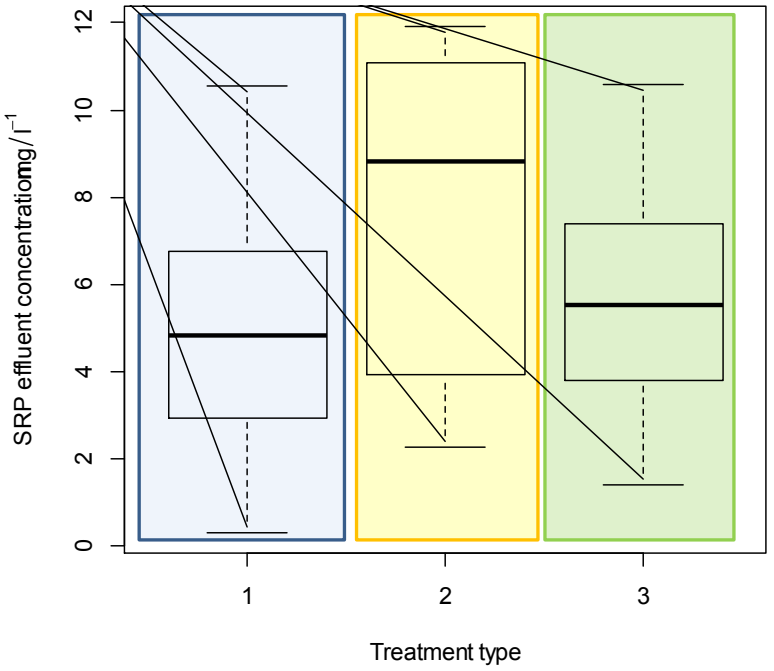
Concentration of SRP between PSS and between PSS treatment type

Median = 4.95 mgl^{-1} (range 0.32 – 11.91 mgl^{-1})





$F_{(6,40)} = 12.97$, p = <0.0001, n = 47

$F_{2,44)} = 0.99$, p = <0.38, n = 47

Primary treatment = 4.83 mg Pl^{-1} (0.32 – 10.56 $mgPl^{-1}$)
Secondary treatment = 8.82 mg Pl^{-1} (2.26 – 11.91 $mgPl^{-1}$)
Tertiary treatment = 5.54 mg Pl^{-1} (1.42 – 10.60 $mgPl^{-1}$)

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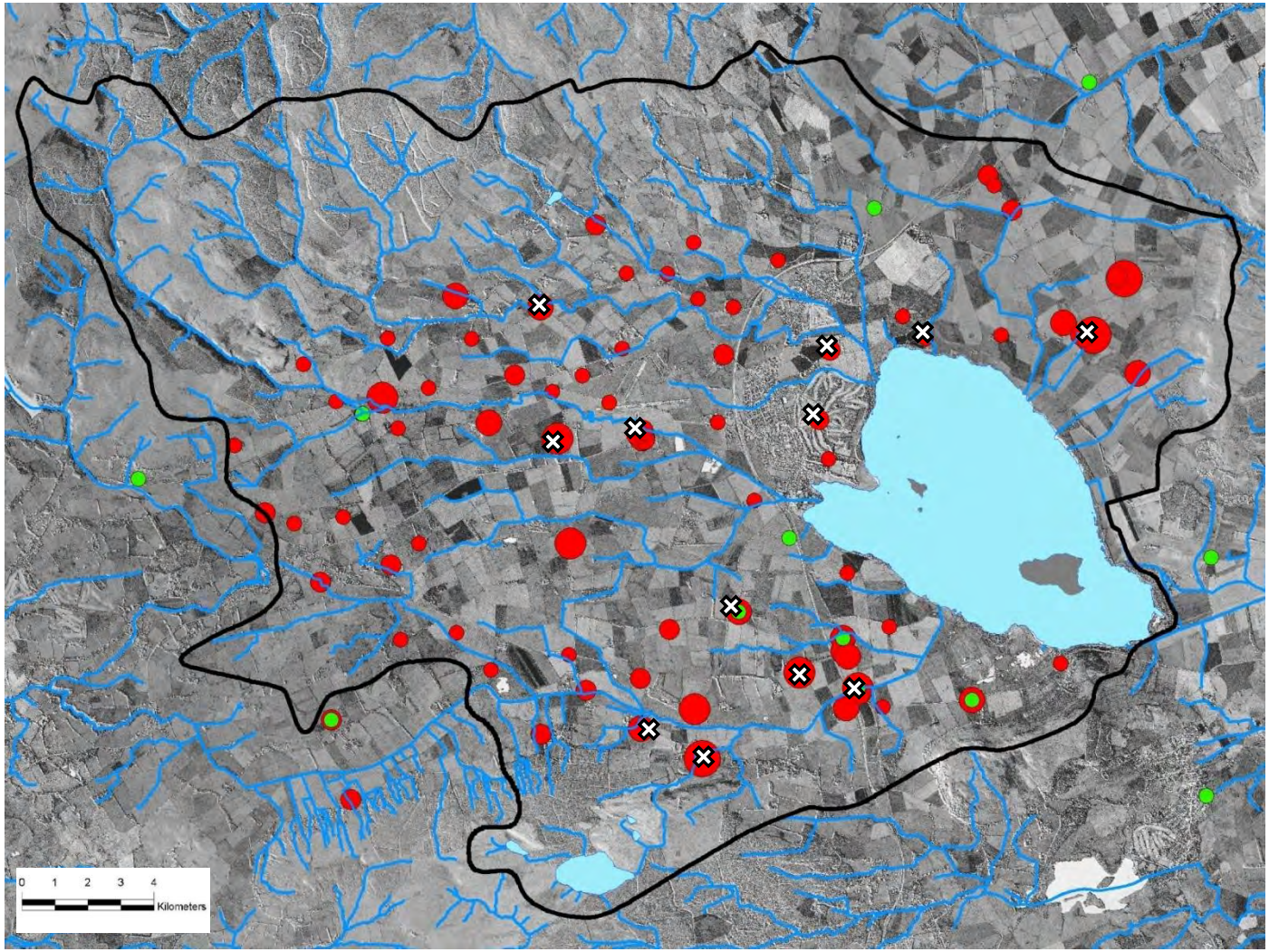
Location of experimental units and method overview



⊠ Experimental units

Questionnaires were used to collect behavioral data from each PSS user.

12 private sewage systems were selected.

5L samples were collected from the final settling tank of each PSS.

Samples were assessed for TP, TSP and FRP using colourimetric spectrophotometry

Samples were also analyzed using (^{31}P-NMR) spectroscopy

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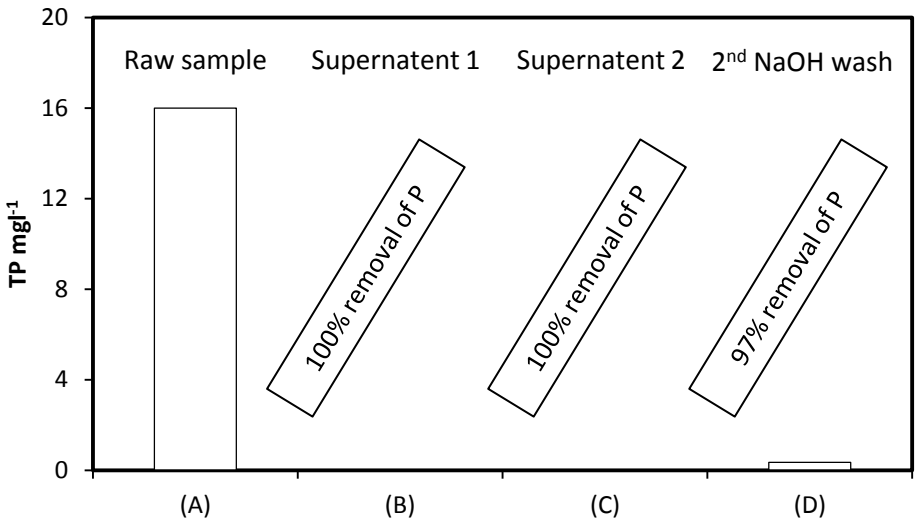
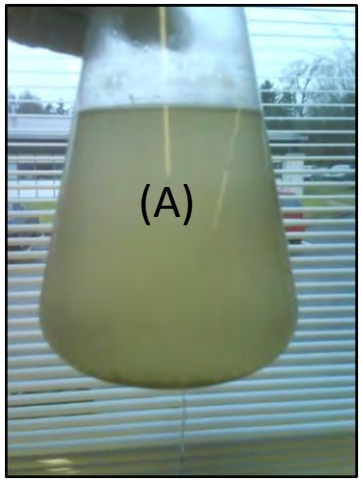
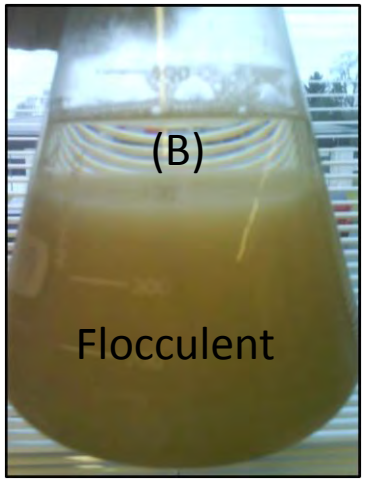
Extraction method for (^{31}P-NMR) analysis



Taking all the phosphorus in 5 litres of effluent and concentrating it into 630ul





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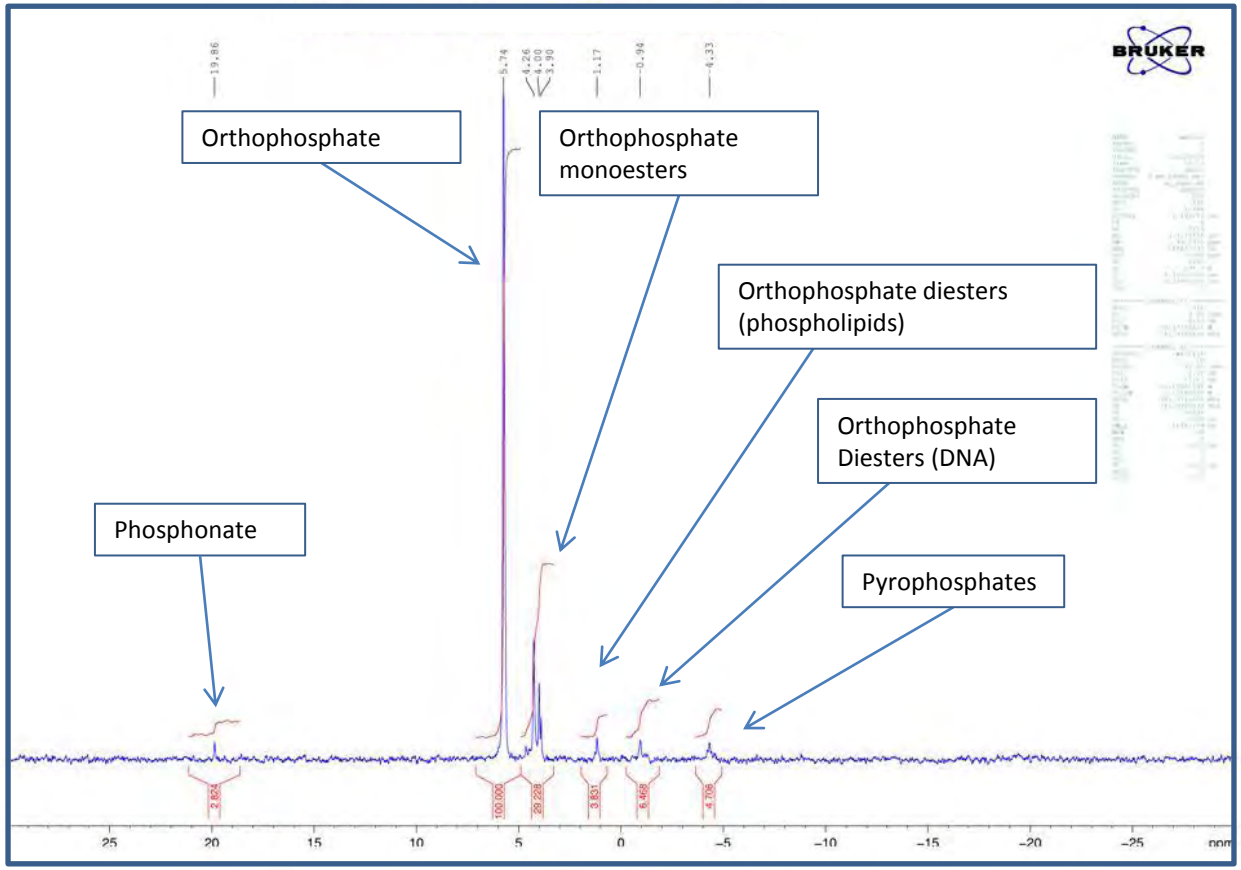
Nuclear magnetic resonance (^{31}P-NMR) spectroscopy



Nuclear magnetic resonance (^{31}P-NMR) spectroscopy showing different compounds present in the effluent of a septic tank in the Loch Leven Catchment, Scotland, UK. Based on Cade-Menun 2010

- 5mm NMR tubes
- 90˚ observation pulse on a Bruker AVIII 400MHz at 25˚C

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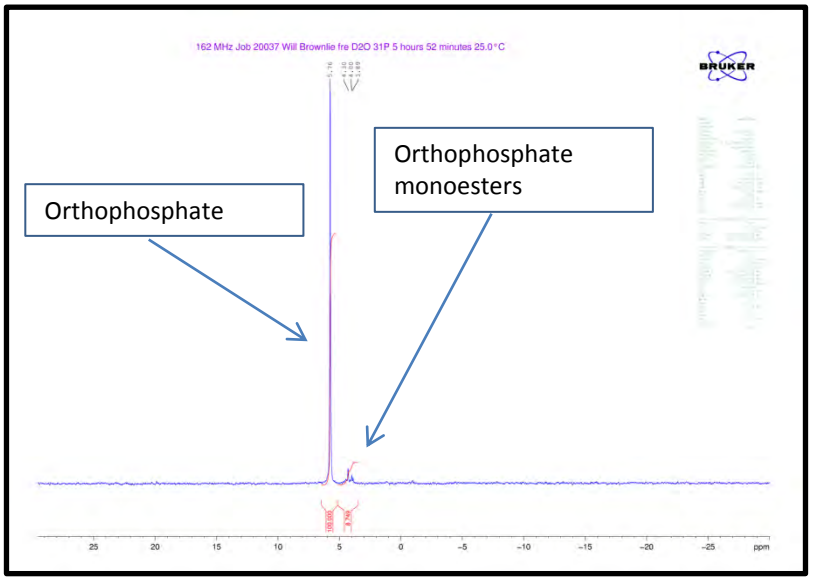
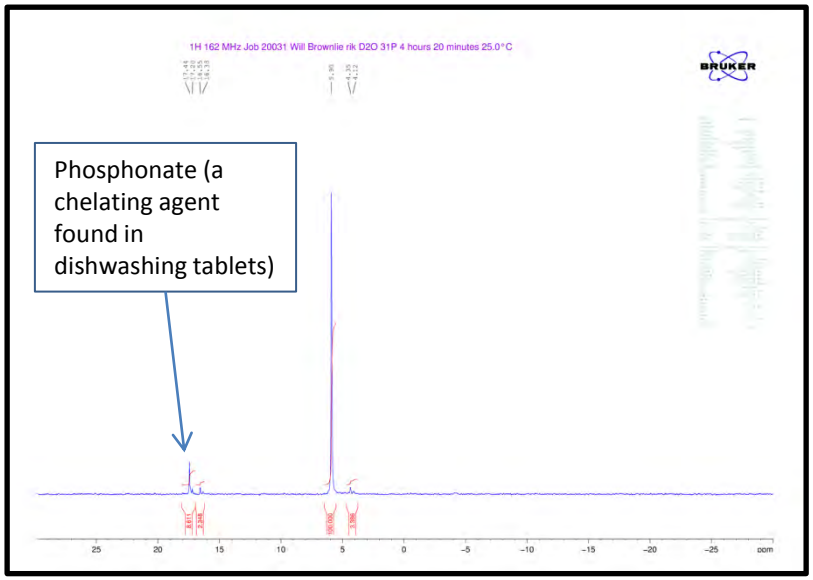
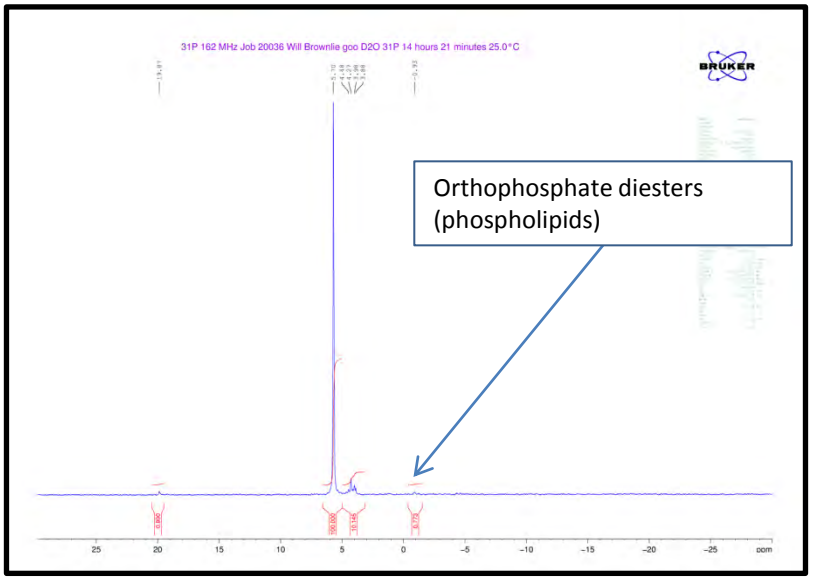
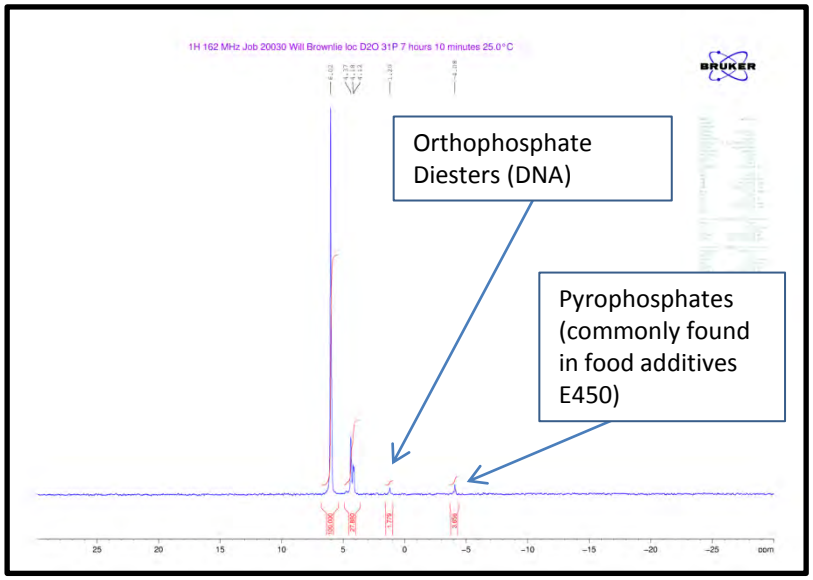
Nuclear magnetic resonance (^{31}P-NMR) spectroscopy

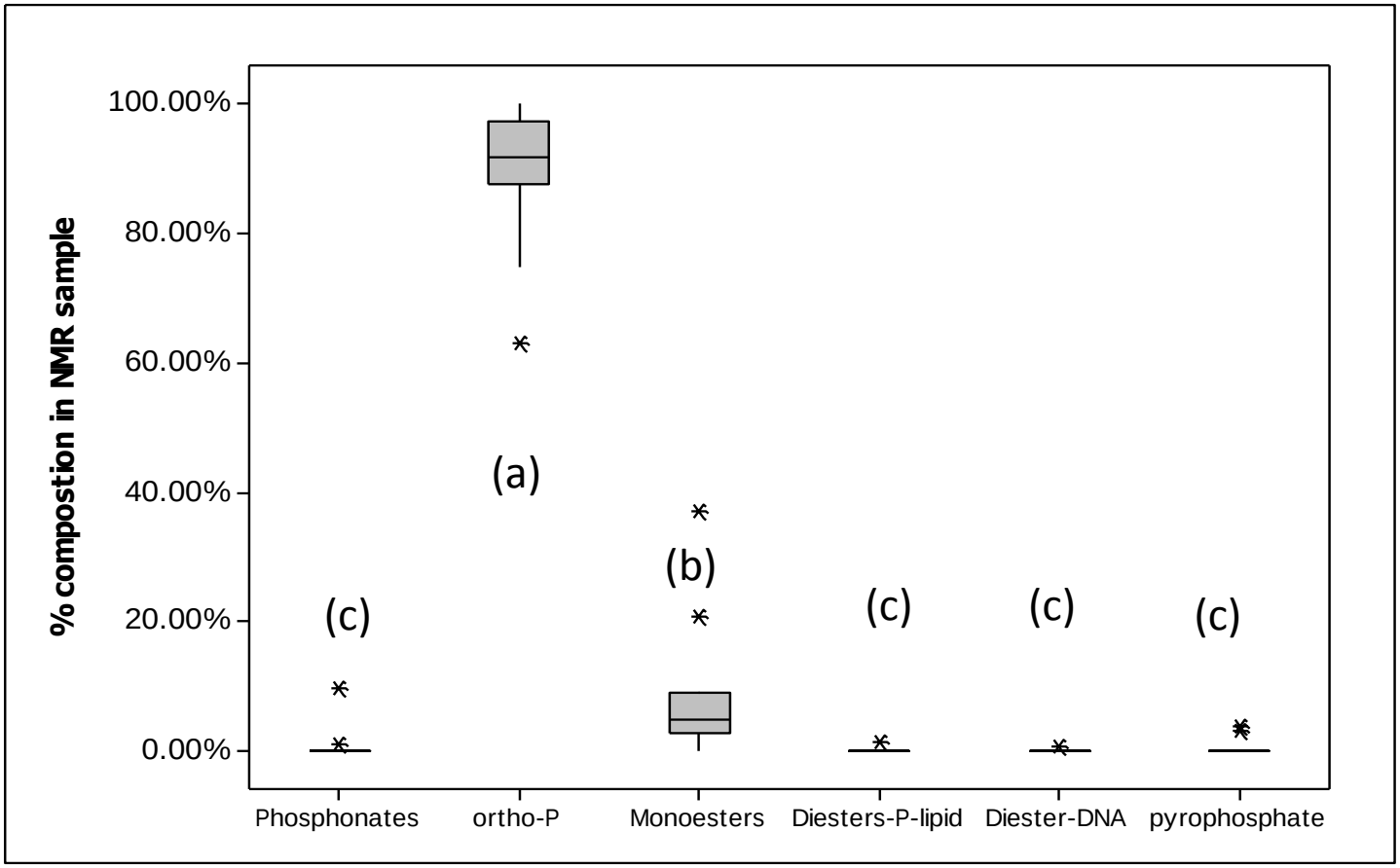








Percentage composition of P compounds in (^{31}P-NMR) samples from PSS



NMR samples contained an average 81.9% orthophosphate and 8.1% orthophosphate monoesters, with trace phosphonate, orthophosphate diesters and pyrophosphonates.

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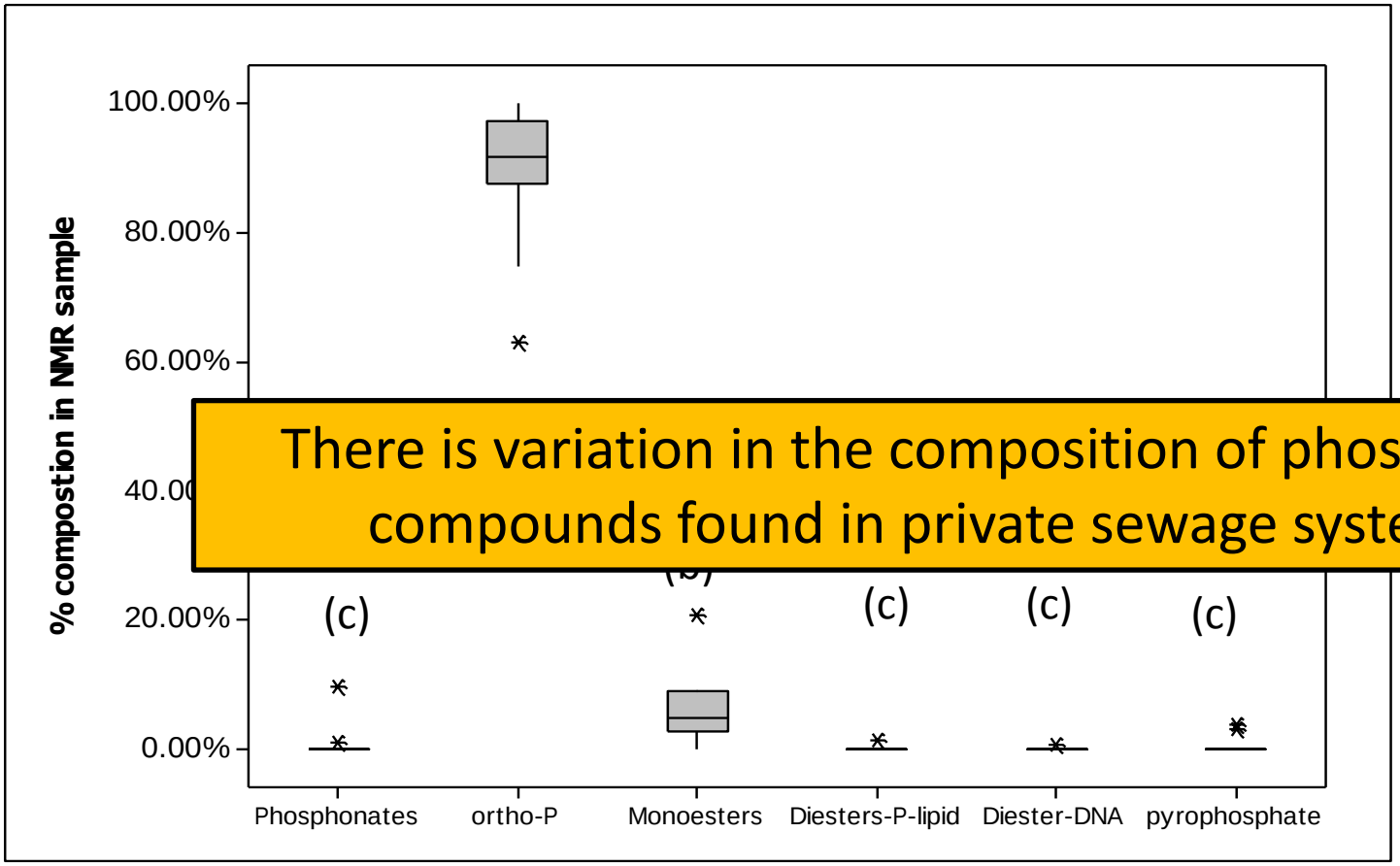
Percentage composition of P compounds in (^{31}P-NMR) samples from PSS



There is variation in the composition of phosphorus compounds found in private sewage systems

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2. Is there variation in the behaviour of private sewage system users

Survey collection of quantitative and qualitative data

- Catchment wide survey 27% answered (n=158)
- Qualitative data collected – peoples opinions about issues related to PSS and what influences their domestic habits
- Quantitative data collected – age, domestic habits, PSS type, household size

  Range of sexes and ages (31-96 yrs old) (56 female, 95 male, 7 unsure?)

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Owners feel responsible for their PSS

- 68% of users believed it was the responsibility of the owner to correctly maintain their septic tank

- 69% felt it is the owners responsibility to fix a septic tank known to be operating incorrectly

Variation in PSS maintenance

Never emptied tank 19%

Have emptied tank 70%

Unsure 13%

Emptied more than a year ago 44%

Emptied less than a year ago 56%

42% had tanks that had become blocked or overflowed

51% of systems had never been blocked or overflowed

(Unsure 8%)

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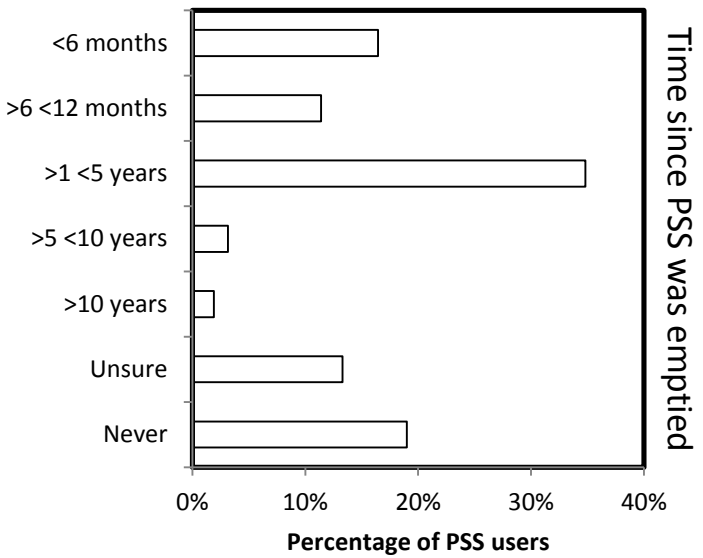
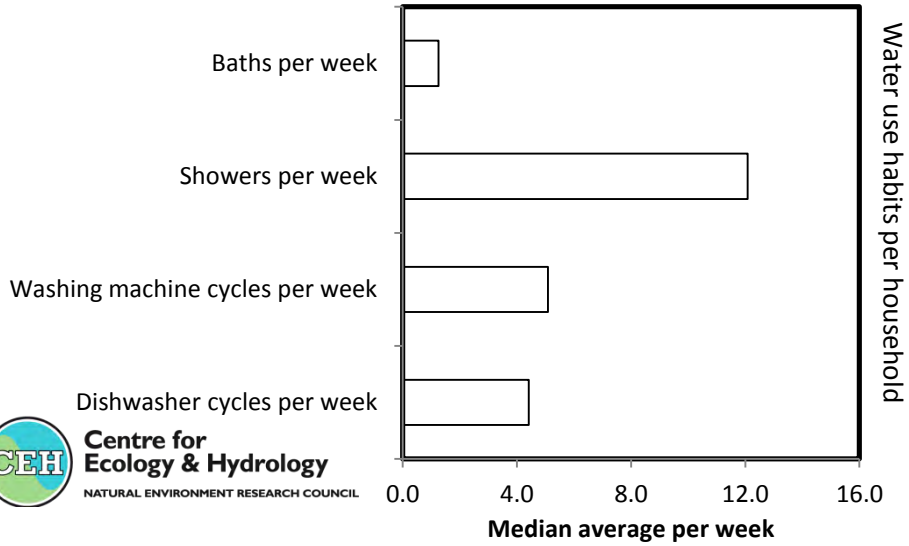
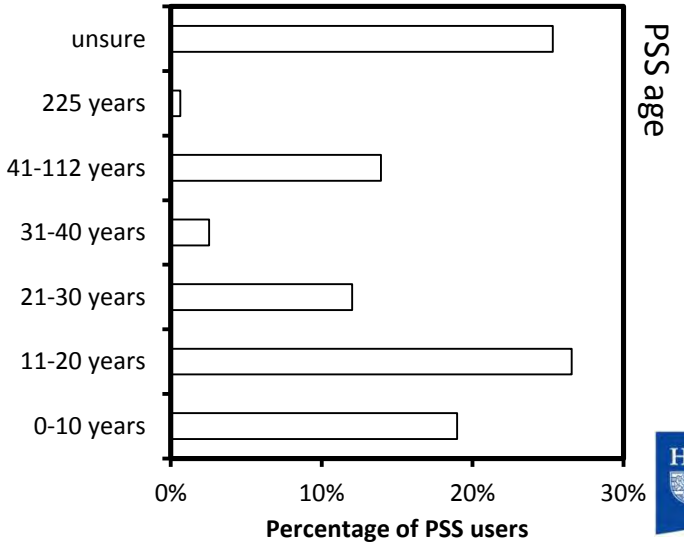
Variation in behaviour of PSS users (n=158)







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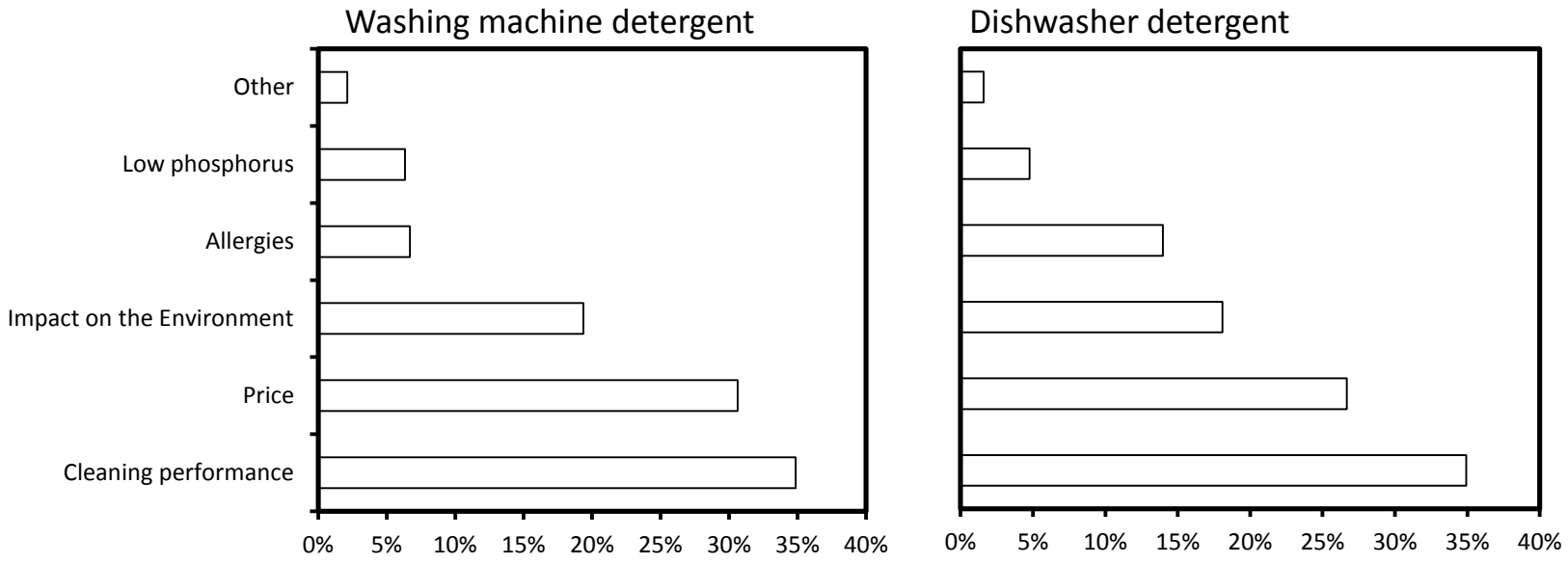
What influences detergent buying choices?



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Information accessibility

Do you feel adequate information is available on correct maintenance

60% No

Do you feel adequate information is available to reduce pollution from septic tanks

54% No

Do you feel adequate information is available to help you make decisions to change your domestic habits to improve septic tank performance

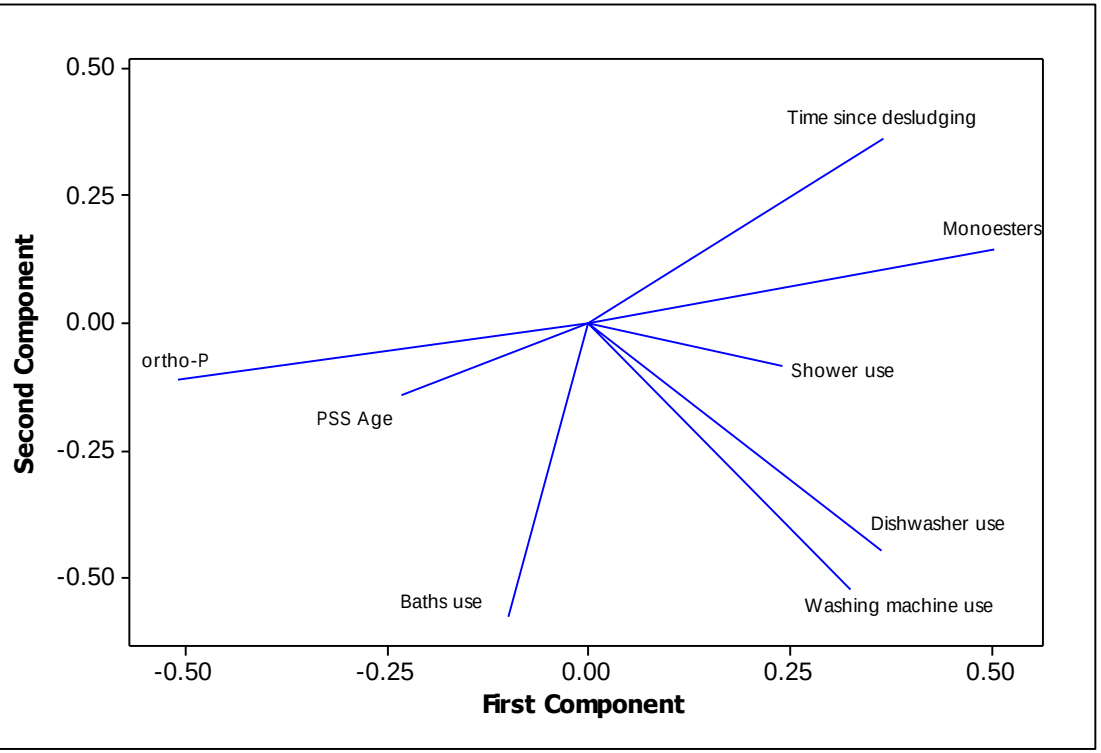
65% No

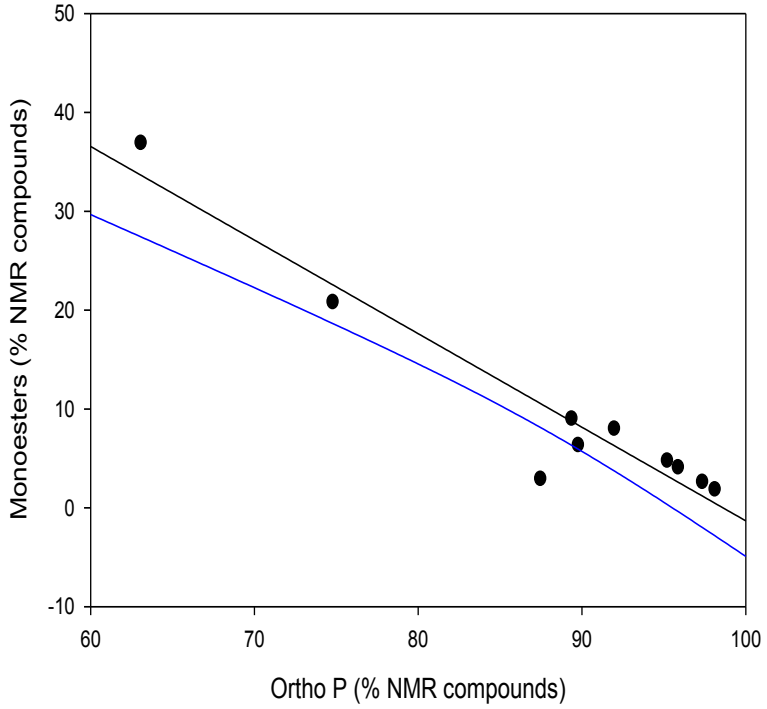
In Summary…

- Owners feel responsible
- Their is a lack in septic tank friendly behaviour
- Owners want more information on how to be septic tank friendly

3. Does user behaviour impact the type of phosphorus compounds found in private sewage systems

Relationship between orthophosphate and orthophosphate monoester (n=12)





p-value	Equation of line y - ….	R^2 (adj)
0.000	Monoesters = 0.925 - 0.935 ortho-P	91.60%

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Human behaviour does impact the P composition of PSS

Stepwise regression was used to identify the most important explanatory variables, multiple regression was then used to calculate formulae to describe the relationship variables have on different P pools.

Relations	*P*-value	Equation of line y - ….	R^2 (adj)
TP	0.040	= 10.8 + 0.113 time since PSS last emptied	35.80%
FURP	0.005	= 0.020 + 0.102 Washing machine use	31.10%
Orthophosphate	0.001	= 1.05 - 0.00261 time since PSS last emptied - 0.0107 Dishwasher use - 0.00648 Shower use	90.10%
Orthophosphate monoesters	0.001	= - 0.0116 + 0.00251 time since PSS last emptied + 0.0138 Dishwasher use + 0.00346 Shower use - 0.00206 PSS Age	93.10%

Human behaviour does impact the P composition of PSS

Stepwise regression was used to identify the most important explanatory variables, multiple regression was then used to calculate formulae to describe the relationship variables have on different P pools.

Relations	*P*-value	Equation of line y - ….	R^2 (adj)
TP	0.040	= 10.8 + 0.113 time since PSS last emptied	35.80%
FURP	0.005	= 0.020 + 0.102 Washing machine use	31.10%
Orthophosphate	0.001	= 1.05 - 0.00261 time since PSS last emptied - 0.0107 Dishwasher use - 0.00648 Shower use	90.10%
Orthophosphate monoesters	0.001	= - 0.0116 + 0.00251 time since PSS last emptied + 0.0138 Dishwasher use + 0.00346 Shower use - 0.00206 PSS Age	93.10%

The longer a PSS is left without being emptied the greater the proportion of inorganic P in their PSS.

Showers and dishwashers are a source of orthophosphate monoesters to PSS

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Conclusions

- **Is there variation in the concentration and composition of phosphorus compounds found in PSS?**

  TP concentration did not significantly alter between tanks. Composition of P compounds in PSS does.

- **Is there variation in behaviour of private sewage system users?**

  Users display variation in how often they empty there PSS, water usage and the factors that influence their detergent buying choices . Owners feel responsible, in some cases PSS maintenance could be improved, this may be due to lack of knowledge. PSS owners want more information on how to be septic tank friendly

- **Does user behaviour impact the type of phosphorus compounds found in private sewage systems?**

  The length of time a PSS is not emptied for plays a key role in the P composition of PSS (possibly due to microbial conversion of organic compounds to orthophosphate), and water use, in particular showers and dishwashers, increase orthophosphate monoester concentration in PSS, possibly to do with retention time of PSS contents.

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