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Assessing pro-environmental behaviour in relation to the management of pollution from private sewage systems.

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Abstract

Recent studies suggest that 80% of the estimated 1.5 million private sewage systems (PSS) in the UK are working inefficiently, potentially threatening drinking water quality and human health, as well as providing a significant source of phosphorus (P) to freshwater bodies, increasing vulnerability to eutrophication. In this report we explore pro-environmental behaviours of PSS users that potentially offer significant reduction in both PSS system failure and P discharge by 1) reducing P input to the PSS by modifying domestic behaviour, and 2) reducing the risk of PSS failure by improving maintenance of the PSS. A detailed questionnaire of 156 PSS users in the catchment of Loch Leven, Scotland, UK, revealed 70% of users feel responsible for maintaining their PSS, 46% are potentially maintaining them ineffectively, nearly 30% have poorly installed systems and 45% report their PSS had, at some point, blocked or overflowed. Our results indicate that the most effective action to improve PSS operation would be to provide better guidance on low P lifestyles and correct PSS maintenance with an improvement in the provision of facilities to support these pro-environmental behaviours.

Keywords: pro-environmental behaviour, phosphorus, septic tanks, private sewage system, policy.

1. Introduction

1.1. Importance of private sewage systems and current control measures

Properties in areas where connections to municipal sewage systems are not available must rely on private sewage systems (PSS) to treat their wastewater (Withers et al., 2012). When operating correctly, PSS offer an effective way of processing sewage. But, if poorly installed or managed, PSS can contaminate groundwaters posing a significant threat to drinking waters and a risk to human health (Súlleabháin et al., 2009; US EPA, 2002a), as well as a potential source of nutrients to freshwater bodies increasing their vulnerability to eutrophication (Ahmed et al., 2005; Arnscheidt et al., 2007; Withers et al., 2013). Recent studies suggested that 80% of the estimated 1.5 million PSS in the UK are potentially working inefficiently with respect to phosphorus (P) losses (Kirk et al., 2003; Selyf-Consultancy, 2002). In the US, one in four homes is served by a PSS; these 26.1 million properties contribute the largest volume of waste water (3.6 10^2 GL $year^{-1}$) to the subsurface (US EPA, 2002a).

Effective river basin management, as outlined in the European Water Framework Directive (EU, 2000), requires accurate estimation and, where necessary, reduction in contributions made by different P sources within the catchment (Edwards & Withers, 2008). Although there is an overall lack of data on both the location and the state of repair of many PSS (May et al., 2010), an estimate has been made in some UK rural catchments of the net P contributions made to water bodies by PSS (May & Dudley, 2007). These range from 3% in Llyn Tegid, Wales (Milliband, 2002) to 40-76% in Black Beck, north England (Hall, 2001). In the US, the estimated proportion of PSS failing to work correctly in 28 states ranged from 0.4-70% (Nelson & Dix, 1999).

While there is a need to make significant reductions in P discharges from PSS, there is little legislation or guidance at a design or installation level to address this (Withers et al., 2013). For example, now PSS can only be installed in Europe if they have the EU standard for PSS design (EU Standard; EN12566-1-7:2000). This does not include a requirement for P control measures. Similarly, the UK Building Regulations 2010: drainage and waste disposal (HM Government, 2010a) and the Building Standards (Scotland) Act 2003 (Scottish Government, 2003) do not consider P discharges within the guidelines for PSS installation. Individual homes connected to PSS do not need a discharge permit under the US Environmental Protection Agency (US EPA) National Pollutant Discharge Elimination System (NPDES) permit program (US Goverment, 2002). Although US regulations for PSS are considered to be the responsibility of the local state (Nelson & Shephard 1998), only 10 states currently have regulations that mention P from PSS, and only 7 translate these into local plans (SORA & NESC, 2012).

In the UK and Ireland, the need to control P discharges from PSS has been recognised in recently developed policy. The Building Regulations 2010 in Ireland (Irish Government, 2010) provide an expected minimum discharge concentration of 2 mg P l^{-1} for PSS in nutrient sensitive areas. And, in the P sensitive catchment of Loch Leven, in east Scotland, a development policy has been introduced outlining mitigation of P from PSS associated with new developments (Loch Leven Special Protection Area and Ramsar Site, 2011), but is potentially ineffective (Brownlie et al., 2014). In general, a reliance on technological solutions (i.e. treatment level) to provide low P output from PSS has been adopted in these policies. In a comparitive study of nutrient loading to subsoils from PSS with either primary or secondary treatment, Gill et al. (2009) observed that reducing P output by increasing the treatment level of PSS is challenging and most PSS are not specifically designed to reduce P discharge. To make significant reductions in P discharge from PSS, such technological solutions may not be sufficient when conducted in isolation and increased pro-environmental behaviour of PSS users may also be required to meet required reductions (Comber et al., 2012; Maloney & Ward, 1973).

1.2. Understanding pro-environmental behaviour

Increasing pro-environmental behaviour of PSS users (i.e. behaviour that causes minimal damage or even benefits to the environment (Steg & Vlek, 2009)), could potentially offer a significant reduction in P discharge from PSS by 1) reducing *P input* to the PSS through modifying domestic behaviour, and 2) reducing *P output* from PSS by improving maintenance of the PSS and thereby reducing risk of system failure (flooding etc.).

The factors that control these behaviours have not been examined previously for PSS users and a better understanding is required. Parallel studies of other pro-environmental behaviours have been made (i.e. recycling, water and electricity usage, and waste disposal). An extensive literature review by Sopha (2011) identified that three core models are used to explain the psychology of environmental behaviours; these are the Theory of Planned Behaviour (Ajzen 1991), the Norm-Activation Theory (Schwartz & Howard, 1981) and the Value-Belief-Norm Theory (Stern, 2000). All have been shown to empirically predict environmental behaviour in multiple studies (De Groot & Steg, 2007; Hansla et al., 2008). These models give a valuable insight into the potential changes that can be made to promote a behavioural choice. However, they show significant weakness in predicting behaviours that are associated with repetition and provide little insight into the impact of habit formulation on the relationship between intention and behaviour (Klöckner, 2013). By combining these models, a framework of the variables that influence both an individual's behavioural intention and their actual behaviour can be constructed (Barr, 2004) (Figure 1).

These variables can be grouped into situational factors, psychological variables and environmental values, and are each composed of a number of 'controlling factors' that are known to be important in predicting behaviour (Table 1).

Geller (2002), later assessed by Steg & Vlek (2009), recommends the use of the following research framework when promoting behaviour change:

1. identify behaviours to be changed,
2. identify the controlling factors that underpin those behaviours,
3. design interventions to change those behaviours, and
4. evaluate the effects of those interventions.

We gathered data from 156 PSS users in the Loch Leven catchment to address stages (1) to (3) of this framework and to address the following objectives: (1) to describe socio-demographic aspects of respondents; (2) to assess the perception that PSS users believe there to be a lack of available information regarding best practice on domestic and maintenance behaviours; (3) to assess interactions between controlling factors and behavioural responses (in relation to PSS maintenance and domestic behaviours); and (4) to discuss the results of this study in the context of encouraging pro-environmental behaviour to reduce P discharge from PSS.

2. Methods

2.1. Study Area

Loch Leven in east Scotland, UK, is a large shallow lake (mean depth 3.9m; surface area 13.3 km^2) with a surface water catchment of 145 km^2 that is dominated (80%) by agriculture (LLCMP; 1999). Due to its high conservation value, both nationally and internationally, it is recognised as a Site of Special Scientific Interest (SSSI), a Special Protected Area (SPA) (UK9004111), a RAMSAR site (UK13033) and is part of the Natura 2000 network. Loch Leven has a well documented history of nutrient pollution, catchment management and recovery (May & Spears, 2012a, 2012b; May et al., 2012). The long term monitoring program at Loch Leven (initiated in 1967; May & Spears, 2012a) has been facilitated by effective cooperation between researchers, policy makers and stakeholders making it an internationally important research site (May & Spears, 2012a).

2.2. Identifying behaviours to be changed

Domestic P sources were identified from the peer reviewed literature in which the P contribution to wastewater from different sources in the UK (Comber et al., 2012), Sweden, (Jonsson et al. 2006) and America (US EPA 2002b) had been assessed (Table 2).

Three main sources of domestic P were identified as human wastes, grey waters from sinks and appliances, and bio-wastes from kitchen disposal units. Those providing the greatest contribution of P to wastewaters that could feasibly be reduced were selected as the main focus of the questionnaire for this study. As such, questions were designed to collect data regarding behaviours that impact on P in grey waters; data were also collected regarding PSS maintenance. Dietary behaviours were excluded from the survey due to the well documented complexities involved in changing such behaviour (Vieux et al., 2012). Biowastes (i.e. food-scraps and carbonated drinks poured down the sink) are considered to be such a minor and largely unavoidable source of P (Comber et al., 2012) that they were also excluded from the survey. Questions were designed to collect information about factors known to facilitate environmental behaviours (Table 1), but in the context of behaviours related to domestic P output and PSS maintenance regime. Background information about the households, properties and PSS was also collected. Questions are summarised in (Supplementary Table 3 and 4).

2.3. Questionnaire design

To encourage a maximal response, the questionnaire was kept short (26 questions), anonymous (sex, age and gender only) and simple to complete (predominantly tick box answers). Care was taken to present non-leading and unbiased questions. Questionnaires were delivered on the 5th of September 2012, with self-addressed postage paid envelopes to make it easy for individuals to return completed forms by the deadline of the 5th of October 2012.

Questionnaires were distributed to 654 addresses within the catchment that were believed to be served by PSS; 156 (24%) were completed and returned. The address list was compiled by the Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage (SNH), Perth and Kinross Council (PKC) and Scottish Water, using ordinance survey data to estimate the number of properties located in postcode areas not served by mains sewerage schemes.

2.4. Statistical analysis

Using the statistical software R version 2.51.1 (R-CORE-TEAM, 2012), data were analysed to test for relationships between controlling factors. Mosaic plots were used to assess whether:

- respondents who stated that 'impact on the environment' influenced the detergent that they bought, also considered 'low P content' to be important,
- PSS failures (i.e. becoming blocked, overflowing or producing a bad smell) were affected by the time since the septic tank had last been desludged,
- perception of the degree of personal responsibility to maintain a PSS correctly was related to the time since the septic tank had last been desludged, and
- availability of adequate information on correct PSS maintenance affected perception of the level of personal responsibility to correctly maintain a PSS.

Plots were created in R, using the 'mosaic' function within the Visualizing Categorical Data ('vcd') package (Meyer et al., 2012) and strucplot framework (Meyer et al., 2006a) with 'hcl' residual-based shading (Zeileis et al., 2007). Mosaic plots allow the counts of contingency tables to be visualised (tile size is proportional to cell count). The Pearson Chi-Square Test was used to test if the pattern of data observed (in plots) was significant. Only those plots that were significant (i.e. $p \leq 0.05$) are reported, and are considered an accurate representation of the entire population. Cell shading was used to represent the sign and magnitude of Pearson residuals (standardised deviations of observed from expected values) (Meyer et al., 2006b; Zeileis et al., 2007). Cells with a Pearson residual of >2 or <2 represent a significant departure from independence at the 95% confidence level and are shaded. Shading is not used to visualize significance, but the pattern of dependence (Zeileis et al., 2007). Only responses from users that provided answers to both questions in each mosaic plot were used (accounting for variation between the n-value of the mosaic plot and its two individual questions).

3. Results

3.1. Socio-demographic variation

Respondents were asked how many properties shared their PSS. Sixty percent of respondents stated that no other property shared their PSS, whilst 18% shared their PSS with more than five other properties (range of 0-60, SD = 8.72) (Figure 2a). When asked where their PSS drains to, 62% of respondents stated ‘soakaway’, 15% stated ‘direct to river’, 4% selected ‘open drainage ditch’ (Figure 2b). The responses to questions regarding the socio-demographic variation of respondents (questions 1-8) are summarised in Supplementary Table 3.

3.2. Controlling factors for domestic P behaviour and PSS maintenance

The mean number of dishwasher cycles, washing machine cycles, showers and baths taken per person per week was 1.72 (range of 0-7, SD = 1.45), 2.12 (range 0-10, SD = 1.39), 4.62 (range 0-14, SD = 2.58) and 0.95 (range 0-7, SD = 1.62), respectively (Figure 2c). Respondents were asked to estimate the percentage of PSS in the Loch Leven catchment not operating correctly; 16% considered ‘0-25%’, 25% considered ‘26-50%’, 6% considered above 51%, whilst 52% did not provide an answer (Figure 2d). The responses to questions regarding P producing domestic behaviours and the factors that control them (questions 9-16), and those regarding PSS maintenance and the factors that control them (questions 17-23) are summarised in Supplementary Table 4.

3.3. Interaction between behaviours

Of the respondents, 36% considered ‘impact to the environment’ an influencing factor when buying detergent, whereas only 6% considered both ‘low P content’ and ‘impact to the environment’ to be an influence. In contrast, 61% of respondents felt neither had any influence on the detergents they purchased. This data significantly represents the population ($p = 0.020$, $n = 156$) (Figure 3a).

Respondents were asked if their PSS had, at some point, failed to work properly (i.e blocked, over-flowed or produced a bad smell), and how long it had been since they had last desludged their septic tank. Of the respondents, 47% had desludged their septic tank within the last 12 months, 27% had both reported failure, and had desludged their septic tank within the last 12 months. Conversely, 17% of respondents that had never desludged their tank, and 12% had stated their septic tank had not failed and had never desludged their septic tank ($p = 0.042$, $n = 129$) (Figure 3b).

Of the respondents, 53% had not desludged their tank within the last 12 months;

whilst 40% had not desludged their tank within the last 12 months whilst feeling correctly maintaining a PSS was the responsibility of the private property owner ($p = 0.0075$, $n = 129$) (Figure 3c). Of the respondents, 69% felt correctly maintaining a PSS was the responsibility of the private property owner; whilst 43% felt that although the private property owner was responsible to maintain their PSS correctly there was not adequate information available with which their behaviours could be informed ($p = 0.049$, $n = 141$) (Figure 3d). The data for PSS failure and connection of PSS to roof run-off or reports of cracks in PSS was not sufficient to significantly represent the population ($p = 0.27$, $n = 126$).

4. Discussion

4.1. Interaction of controlling factors

The results of our survey indicate that most respondents did not feel that they had access to adequate information to help them change their behaviour to achieve reductions in the amount of domestic P they produce or correctly maintain their PSS to reduce P discharge to the environment. Recognition of a specific problem and evidence based understanding of the solutions to this problem are, clearly, a prerequisite to informing pro-environmental behaviour. However, the assumption that increasing environmental knowledge and awareness is a direct determinant of pro-environmental behaviour is incorrect (Bamberg, 2003; Kollmuss & Agyeman, 2002). Silverman (2005) showed that door to door delivery of information outlining better PSS management can be used to successfully educate individuals in relation to PSS maintenance, but did not necessarily result in a significant change in user behaviour. Isolated educational programmes that do not address other controlling factors of behaviours are often inefficient (Barr, 2004). The current study highlights a number of the controlling factors of behaviours regarding domestic P output and PSS maintenance and introduces interactions between them, emphasising the need to address multiple factors if behaviours are to be changed.

4.2. Factors that affect domestic P input to PSS

In this survey, purchasing choice of detergent was influenced most by price, followed by cleaning performance. Although in the UK, use of low P detergents and reduction in the volume of detergents used could potentially offer < 28% reduction in P entering PSS (Comber et al., 2012), respondents did not consider ‘impact on the environment’ when buying detergent and, of those that did, most did not identify ‘low P content’ as important. Results indicate that individuals consider that the P content of detergents does not impact the environment or consider this impact minimal or unavoidable. Assuming that individuals want to behave in a manner that does not cause harm to the environment, this survey shows respondents do not have knowledge of the problem or potential solutions. This corresponds to low ‘perceived behavioural control’, (i.e. an individual’s perception of responsibility and of their competence to change behaviours that will achieve a desired outcome) a known prerequisite to choosing pro-environmental behaviour (Klöckner, 2013).

The perceived value of using a low P content detergent (i.e. reducing P output of PSS) must outweigh the perceived value of a detergent that is cheap and cleans well. The Theory of Planned Behaviour states that individuals will choose low cost-high benefit behaviour (Ajzen, 1991; Barr, 2004). Currently this may not be satisfied; greater information on detergent packaging may raise awareness. Köhler (2001) highlights that ‘ecolabels’ highlighting detergent P content are inherently complex to produce, due to the general lack of clarity in the necessary message that would need to be included.

In the US, environmental policy has been implemented to reduce the impact of P from detergents; the sale of detergents with more than 0.5% P has been banned in sixteen states due to the risks that they pose to freshwaters (Lusk et al., 2011). This has resulted in a reduction of P in wastewaters by 40-50% (US EPA 2002b). Since June 2013, the EU has prohibited the sale of consumer laundry detergents that provide ≥ 0.5 g of P per standard dosage (for a single cycle); by 2017 the sale of dishwasher detergents with ≥ 0.3 P g per standard dosage (for a single cycle) will also be banned (EU, 2012). This is encouraging, but this regulates only P ‘concentrations’ in detergent, the ‘amount’ (or P load) of detergent used is still determined by individual behavioural choice. Providing accurate measuring cups for liquid detergents and the use of detergent in tablet form are effective measures for controlling the quantity of P used in each wash (Köhler, 2006).

Habitual behaviour, such as dishwasher, washing machine and detergent use, is often not preceded by intricate reasoning and is directed by automated cognitive processes. Behaviour repeated annually or bi-annually is greatly determined by intention (i.e. desludging a septic tank), whilst weekly behaviour (i.e. detergent purchase and use) is influenced by habit strength (Ouellette & Wood 1998). Such behaviours can be difficult to change (Wood et al., 2005). Interventions that disrupt the context that maintain habits use regular reminders (Nilsen et al., 2012); Chan (1998) demonstrates how the mass media play an important role in establishing social norms.

Although not explored within this survey, it should be noted that 30-70% of P in wastewater can come from urine and faecal derived nucleic acids and tri-phosphates (Lusk et al., 2011) and may exceed detergent P load from domestic sources. Additives in processed foods can add an extra 0.47-1.00 g P day $^{-1}$ to diets and are often ‘non-essential’ (i.e. added for aesthetic and preservative reasons) (Comber et al., 2012; Uribarri & Calvo, 2003). Reduction in the use of such additives at an industry level may be required if significant domestic P reductions are to be made.

4.3. Factors that impact maintenance behaviour

Regular septic tank desludging is recommended as good maintenance practice (Univeristy of Minnesota 1998; SEPA et al. 2006; US EPA 2002b). However, there is a general public perception that PSS are self-maintaining and tanks do not need regular emptying (Moelants et al., 2008). In this survey, the number of PSS running inefficiently is greatly underestimated by the public, only 3% of respondents considered 75-100% of the PSS in the Loch Leven catchment were operating inefficiently (current UK estimates suggest 80%; 42% in this study). Without such knowledge, moral obligations to address the issue are diminished and social norms (the combination of the social pressure perceived by an individual to perform the behaviour, multiplied by their willingness to do so) are reduced. From the large variation in responses, it is suggested that there is no established social norm with regards to the regularity of septic tank desludging and, therefore, little social pressure to do so. This is confounded by the variety of different information available regards suitable desludging frequency, ranging from 1-6 years (Aberdeenshire

Council, 2012; Angus Council, 2012; SEPA, 2006; US EPA, 1999), whilst others state septic tanks should be emptied in accordance with the manufacturers specifications, although the manufacturers details may not be known by many PSS owners (HM Government, 2010b).

The required frequency of desludging of a PSS depends on the capacity of the tank and the volume and type of waste that it receives, and may, therefore, be considered PSS specific (Withers et al., 2012). Moore (2000) provides a matrix in which household size and tank capacity can be used to estimate desludging frequency (i.e. a family of two with a 500 gallon (2273 l) tank should empty their tank every 2.6 years). In the UK, a lack of data on PSS (Withers et al., 2012) could make such calculations difficult. It is, therefore, challenging for users to determine the correct maintenance practices for their PSS.

In our survey, of those respondents that had desludged their septic tank within the last 12 months, the majority reported that their PSS had, at some point, also failed to work correctly. Conversely, the majority of respondents that had never desludged their tank did not report failure. This suggests that septic tanks may be commonly emptied as a response to failure as opposed to as a preventative step to avoid failure, and/or that some PSS are poorly installed or inadequately sized causing failure despite regular emptying. A comprehensive field survey of PSS is needed to identify those tanks that are working incorrectly and greater public information is required to raise awareness of the importance of desludging regimes in reducing P discharges to the environment from PSS.

In shared systems, responsibility for tank emptying can be unclear (Withers et al., 2012). Although, in this survey, nearly 40% of respondents reported a shared PSS, we found that nearly 70% of respondents felt that it was their personal responsibility to correctly maintain their PSS. Although responsibility is a core controlling factor of behaviour, it did not equate to the behaviour of regular annual desludging (i.e. less than half had desludged their septic tanks within the last 12 months). Nearly 70% of respondents felt that there was inadequate information to inform their PSS maintenance regime leading to the suggestion that perception of responsibility coupled with the provision of sufficient information may result in improved overall behaviour. However, nearly a third of respondents denied any responsibility for maintaining or fixing their PSS, a perception that clearly needs to be addressed.

5. Conclusion

This survey highlighted the need for better education and information on PSS maintenance and the input of P to these systems from domestic sources. Our results demonstrate that a large proportion of PSS users feel responsible for correctly maintaining their PSS, but are potentially not maintaining them effectively (i.e. lack of regular annual desludging) or have poorly installed or inadequate systems (i.e. unaddressed cracks in PSS with some still receiving roof runoff). To facilitate target behaviours, situational barriers, such as the provision of cheap, accessible behavioural alternatives that are considered the social norm, must first be addressed before attempts are made to change underlying motivational factors through education.

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Figure and Table Legends

Figure 1. Framework explaining the variables which influence behaviour and modify the relationship between behavioural intention and actual behaviour (modified from Barr 2004).

Table 1. Controlling factors that influence behaviour and behavioural intention, proposed in the framework of Barr (2004).

Table 2. Phosphorus contribution of different domestic sources to wastewaters from households in the UK, Sweden and USA.

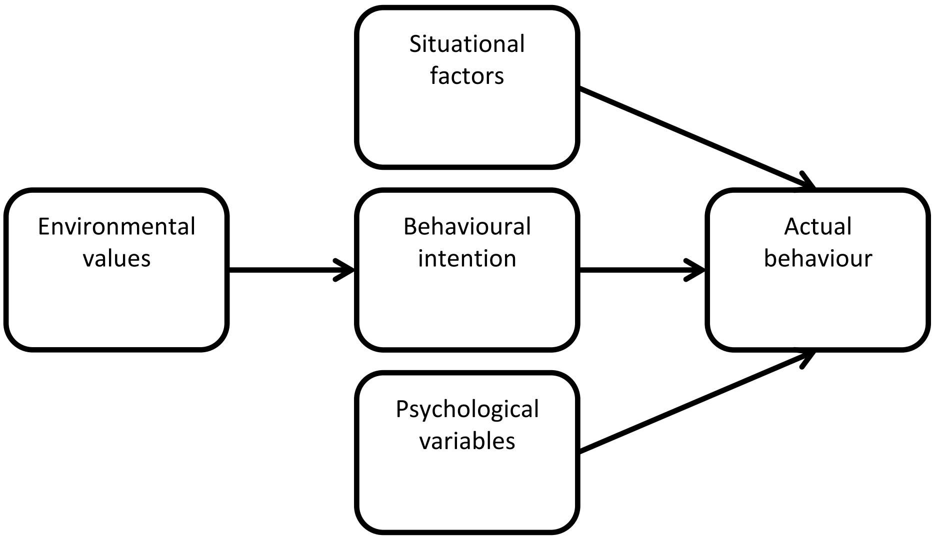
Figure 2. a) The proportion of private sewage system in Loch Leven that drain to soakaways, rivers or streams, drainage ditches, reed beds, other or unknown destinations (n=156), b) the proportion of households in Loch Leven that share private sewage system with other households (n=156), c) the mean water appliance use (disposal units, baths, showers, washing machine and dishwashing machine cycles), per person per week (n=156), d) proportion of respondents who estimate the percentage range of PSS work inefficiently in the Loch Leven catchment was 0-25%, 26-50%, 51-75%, 76-100% and those who didn't provide an answer (n=156).

Figure 3. a) relationships between respondents that state 'low phosphorus content' and 'impact to the environment' influence their washing machine purchasing decisions, b) relationships between respondents who reported their septic tank to have failed to work correctly and the time since their septic tank had last been desludged, c) relationships between respondents who believe the private property owner is responsible for maintenance of the private sewage system and the time since their septic tank had last been desludged, d) relationships between respondents who believe there is or is not adequate infromation available on correct maintenance of PSS and those who believe the private property owner is responsible for maintenance of the PSS.

Supplementary table 3. Survey questions concerning socio-demographic variation and domestic behaviour, the controlling factors they address and explanatory statistics describing responses.

Supplementary table 4. Survey questions concerning maintenance behaviour and the public perception of the problem, the controlling factors they address and explanatory statistics describing responses.

Figure 1.


Situational factors
Environmental values
Behavioural intention
Actual behaviour
Psychological variables

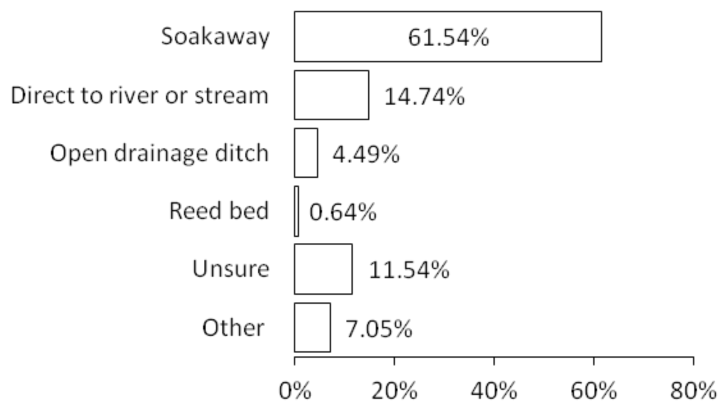


Figure 2a.

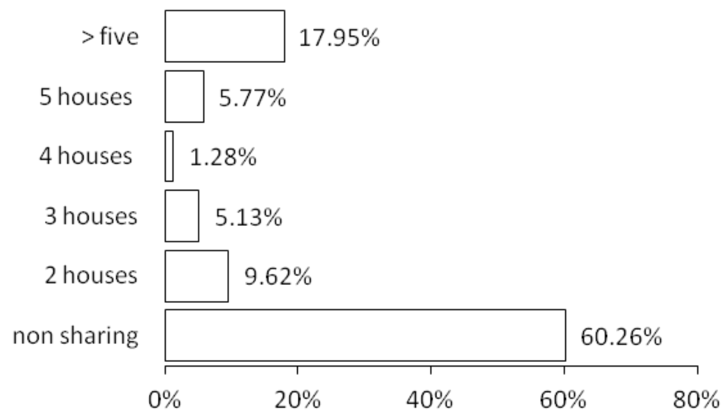


Figure 2b.

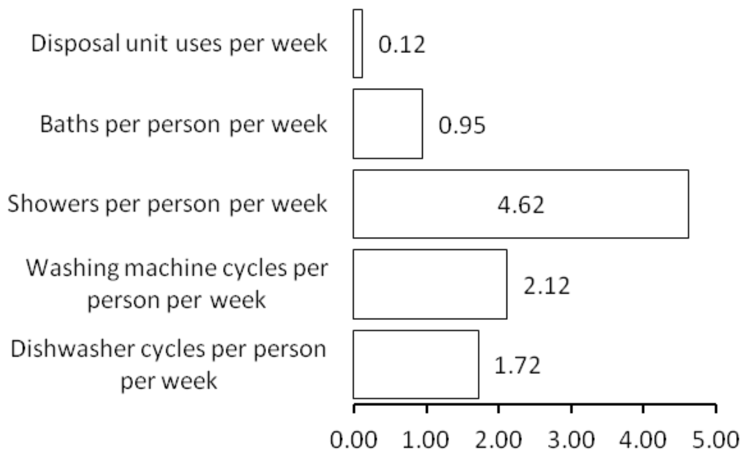


Figure 2c.

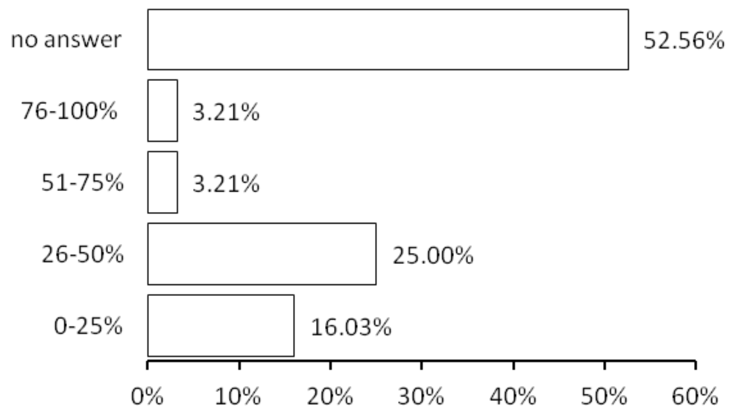


Figure 2d.

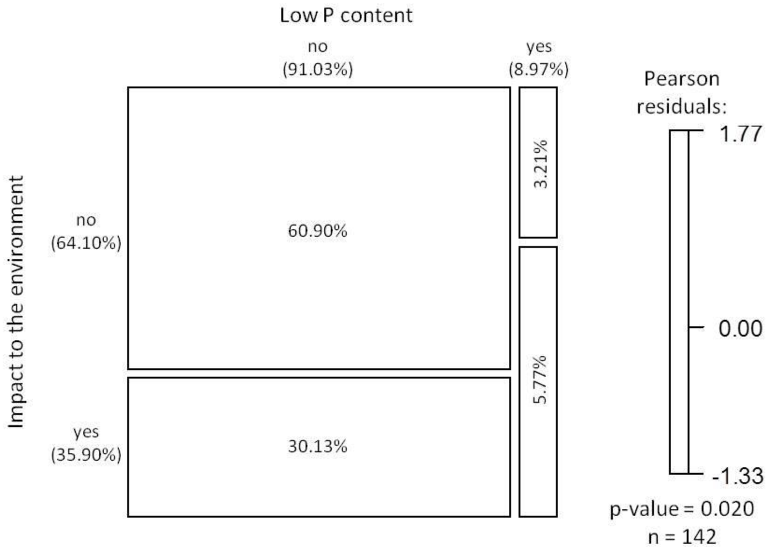


Figure 3a.

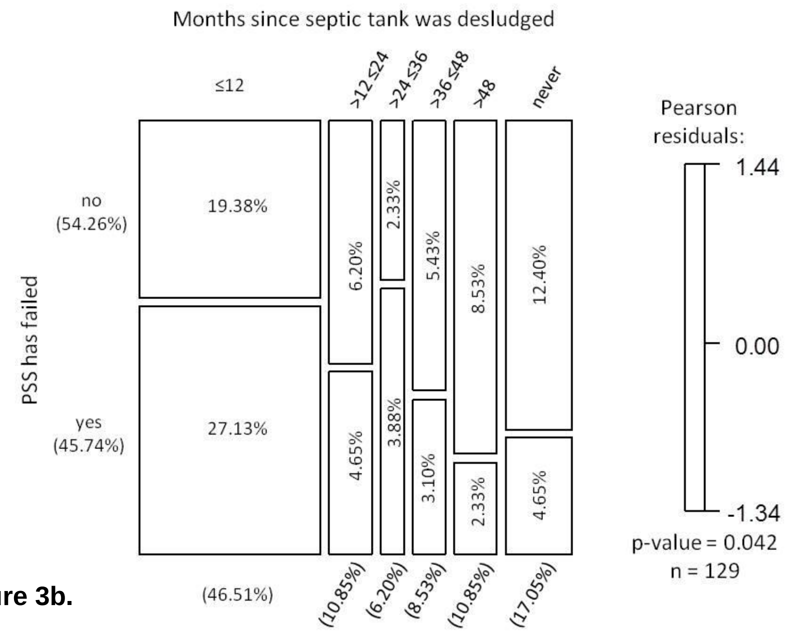


Figure 3b.

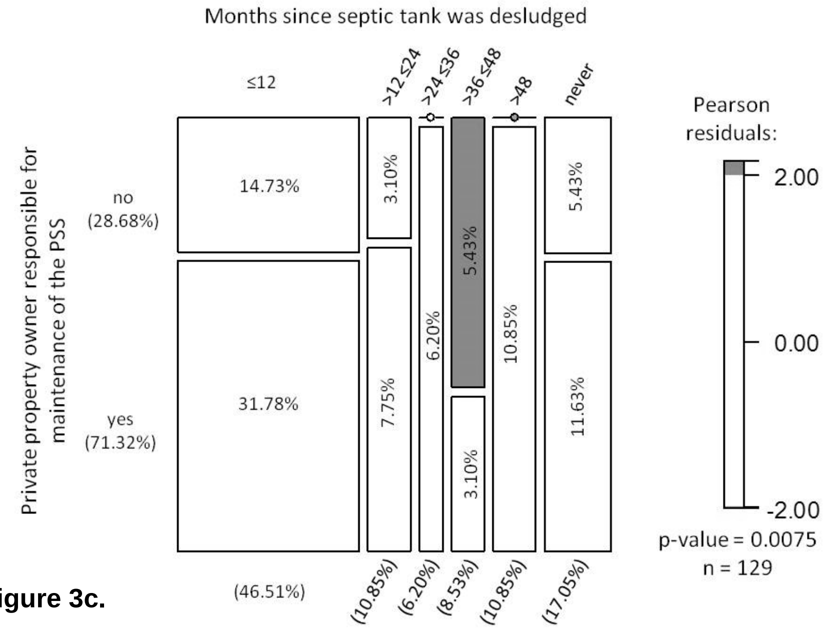


Figure 3c.

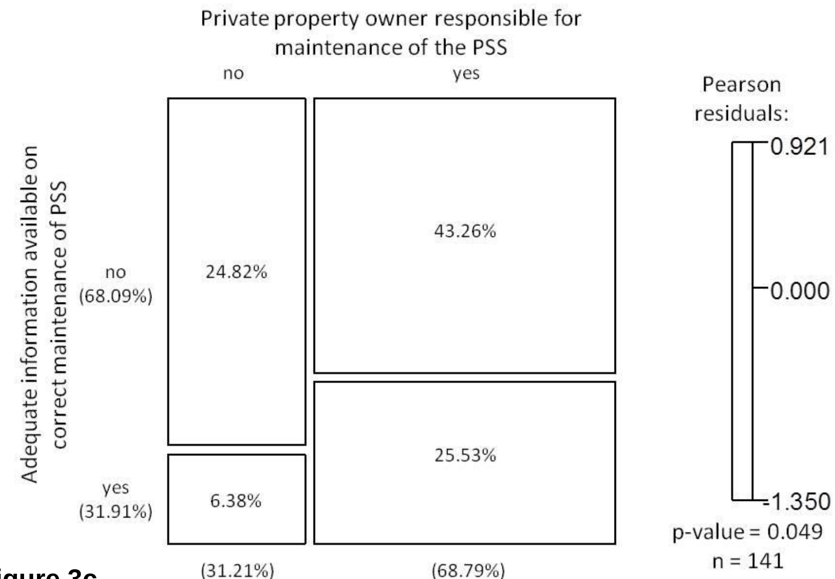


Figure 3c.

Variable Group	Controlling factor	References
Situational Factors	Provision of a range of facilities to perform behaviour	(Barr, 2004)
	Socio-demographic variation	(Saphores et al., 2012; Schultz et al., 1995; Stern et al., 1993)
	Low cost-high benefit	(Ajzen, 1991; De Groot and Steg, 2008)
	Knowledge of the problem	(Barr, 2004; Schahn and Holzer, 1990)
	Knowledge of how the problem can be solved	(Barr, 2004)
Psychological Variables	Perceived behavioural control: • self-efficacy to perform the behaviour • responsibility to perform the behaviour • optimism the result is successful	(Ajzen, 1991; Klöckner, 2013; Schwartz and Howard, 1981; Stern, 2000)
	Personalisation and localisation of the problem	(Eden, 1993)
	Social Pressure	(Baca-Motes et al., 2013; Chan, 1998; Tucker, 1999)
Environmental Values	Ecological world view • Higher score on the NEP (Dunlap et al., 2000)	(Dunlap et al., 2000; Klöckner, 2013; Steel, 1996; Thompson and Barton, 1994)

Table 1.

Phosphorus (P) Sources	UK study (Comber *et al* 2012)		Swedish study (Jonsson *et al* 2006)		U.S. study (U.S. EPA 2002)	
	P contribution to wastewater (g P $capita^{-1}$ day^{-1})	% total	P contribution to wastewater (g P $capita^{-1}$ day^{-1})	% total	P contribution to wastewater (g P $capita^{-1}$ day^{-1})	% total
Human Waste						
Food additives	0.59	28%	-	-	-	-
Faeces	0.21	10%	0.49	21%	-	-
Urine	0.61	29%	0.90	38%	-	-
Total from human waste	1.41	67%	1.39	59%	1.60	59%
Grey waters						
Washing machines	0.28	13%	-	-	-	-
Dishwashers	0.18	8%	-	-	-	-
P dosing of tap water	0.13	6%	-	-	-	-
Personal care products	0.02	1%	-	-	-	-
Total from grey waters	0.60	28%	0.68	29%	1.00	37%
Biowaste						
Total from biowaste	0.1	5%	0.27	12%	0.10	4%
Overall Total	2.11	-	2.34	-	2.70	-

Table 2.

Questions	Controlling factor or behaviour investigated	Response	Unit
Socio-Demographic Characteristics			
1. What sex are you?	socio-demographic variable	Male (61%), female (35%), no answer (4%)	sex
2. How many people live in your house?	socio-demographic variable	2.52 (mean), (SD = 1.19, n = 156)	people
3. How old are you?	socio-demographic variable	56.55 (mean), (SD = 12.80, n = 146)	years
4. How old is your property?	housing demographic	90.78 (mean), (SD = 83.10, n = 151)	years
5. How old is your PSS?	housing demographic	29.52 (mean), (SD = 32.80, n = 122)	years
6. How long have you lived at your address?	housing demographic	15.00 (mean), (SD = 83.10, n = 150)	years
7. How many properties are connected to your PSS?	responsibility, personal behavioural control	1 = 60.26%, 2 = 9.62%, 3 = 5.13%, 4 = 1.28%, 5 = 5.77%, > 5 = 17.95%, (n = 122)	properties
8. Where does your PSS drain to?	housing demographic, knowledge of the problem,	soakaway = 61.54%, direct to river = 14.74%, open drainage ditch = 4.49%, reed bed = 4.49%, unsure = 11.54%, other = 7.05%, (n = 156)	drainage destination
Domestic behaviour			
9. How many dishwasher cycles do you run per week?	behavioural response	1.72 (mean) (range 0-7, SD = 1.45, n = 156)	no. $person^{-1}$ $week^{-1}$
10. How many washing machine cycles do you run per week?	behavioural response	2.12 (mean) (range 0-10, SD = 1.39, n = 156)	no. $person^{-1}$ $week^{-1}$
11. How many baths are run in your house per week?	behavioural response	0.12 (mean) (range 0-7, SD = 1.62, n = 156)	no. $person^{-1}$ $week^{-1}$
12. How many showers are run in your house per week?	behavioural response	4.62 (mean) (range 0-14, SD = 2.58, n = 156)	no. $person^{-1}$ $week^{-1}$
13. How many times do use a disposal unit in your house per week?	behavioural response	0.12 (mean) (range 0-7, SD = 0.71, n=156)	no. $person^{-1}$ $week^{-1}$
14. When buying washing machine detergent which of the following, influence which detergent you buy? (multiple ticks allowed)	behavioural response, low cost-high benefit, knowledge of the problem, knowledge of how to solve the problem	price' = 69.23%, 'cleaning performance' = 53.21%, 'impact to the environment' = 30.90%, 'allergies' = 26.92%, 'low P content' = 8.97%, 'other' = 4.49%, (n=156)	influence factor
15. When buying dishwashing machine detergent which if the following influence which detergent you buy? (multiple ticks allowed)	behavioural response, low cost-high benefit, knowledge of the problem, knowledge of how to solve the problem	price' = 69.23%, 'cleaning performance' = 53.21%, 'impact to the environment' = 30.90%, 'allergies' = 26.92%, 'low P content' = 8.97%, 'other' = 4.49%, (n=156)	influence factor

16. Do you feel adequate information is available on how to change your domestic habits to improve the performance of your PSS (i.e. change of household detergent)?	knowledge of the problem, knowledge of how to solve the problem, perceived behavioural control	71.33% = no, 28.67% = yes, 9.09% = no answer (n = 156)	yes or no

Supplementary Table 3.

Maintenance behaviour			
17. Has your septic tank or PSS ever failed to work correctly (i.e. blocked, overflowed or produced a bad smell)?	behavioural response	yes = 42.31%, no = 51.92%, no answer = 5.77%, (n=156)	yes or no
18. Have you ever emptied/desludged your septic tank? And if so, when was the last time you did?	behavioural response	≤12 = 44.23%, >12 ≤24 = 9.62%, >24 ≤36 = 4.49%, >36 ≤48 = 8.33%, >48 = 10.26%, never = 23.08%, (n=156)	months
19. Does your septic tank have any cracks?	responsibility, knowledge of the problem, knowledge of how to solve the problem	yes = 28.85%, no = 56.41%, no answer = 14.74% (n=156)	yes or no
20. Does your septic tank receive roof runoff?	responsibility, knowledge of the problem, knowledge of how to solve the problem	yes = 17.96%, no = 71.16%, no answer = 9.60 % (n=156)	yes or no
21. Who is responsible for correctly maintaining a PSS? (multiple ticks allowed)	responsibility	private property owner = 69.48%, local council = 22.08%, Scottish Water = 21.43%, SEPA = 11.69% other = 3.25%, (n = 154)	n/a
22. Who is responsible for fixing a PSS known to be working incorrectly? (multiple ticks allowed)	responsibility	private property owner = 69.87%, local council = 18.59%, Scottish Water = 17.95%, SEPA = 14.74% other = 5.13%, (n = 155)	n/a
23. Do you feel adequate information is available on how to correctly maintain your PSS?	knowledge of the problem, knowledge of how to solve the problem, perceived behavioural control	67.61% = no, 32.39% = yes, 9.86% = no answer (n = 156)	yes or no
24. Do you feel adequate information is available on measures to reduce pollution from your PSS?	knowledge of the problem, knowledge of how to solve the problem, perceived behavioural control	61.87% = yes, 38.13% = no, 12.23% = no answer (n = 156)	yes or no
Public Perception of the problem			
25. How many PSS in the Loch Leven catchment do you think are working inefficiently?	personalisation and localisation of the problem	0-25%' = 16.03%, '26-50%' = 25.00%, '51-75% = 3.21%, '76-100%' = 3.21%, no answer = 52.56% (n=156)	percentage range of tanks failing
26. Do you feel informed about the current legislation in relation to PSS?	social pressure, knowledge of the problem	yes = 26.28, no = 70.51%, no answer = 3.21% (n=156)	yes or no
27. Do you think PSS should be registered?	social pressure	yes = 67.31%, no = 32.69%, no answer = 7.05% (n=156)	yes or no

Supplementary Table 4.