DOMESTIC ON_SITE WASTEWATER: REAL NEEDS AND RELATIVE RISKS

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ABSTRACT

This paper reviews the literature and identifies some of the gaps and imbalances in current practices of the various on-site wastewater stakeholders. A primary gap identified is the low level of end-user representation in the shaping of policy and industry activities. Adaptive management, research and development and improved understanding of end-users through monitoring and evaluation, are likely to contribute to the effective design, implementation, and sustainability of OWTS, as well as improving processes, and compliance regarding regulatory requirements.

It is argued that the resilience of treatment systems is intrinsically related to the risk of incidents. The more resilient a treatment system is, the greater range of conditions can be dealt with successfully without incidents arising. The focus on N reduction for on-site wastewater treatment units is weakly justified in the context of the real and relative risks the N emissions present. It is a distraction from where the on-site wastewater industry should be putting its efforts to mitigate the real risks and to provide improved levels of service to the end-user of these systems.

Our assessment is based on a decade of designing and implementing onsite wastewater systems in the field, a formal snapshot survey of 20 end-users survey and a review of the literature. Some end-users want to be less constrained by over regulation in adopting innovative management systems while in contrast regulators, backed with improved science, are increasingly concerned about risks.

Public good scientific research of appropriate and resilient on-site wastewater technologies, treatment processes and management systems is recommended in parallel with a thorough study and development of the appropriate indicators and design principles for OWTS, to guide future monitoring and evaluation of OWTS. We conclude that an explicit focus on adaptive management where there is collegial interaction and ongoing mutual learning between design engineers, manufacturer and regulators would enable better practice to become developed most efficiently. In addition, if the same attentiveness was applied to research supporting the effective monitoring and evaluation clients' needs and concerns, which were explicitly incorporated into the adaptive management process, progress may develop more quickly.

KEYWORDS

On-site wastewater; on-site wastewater risks; ecological resilience, monitoring and evaluation, on-site wastewater end-user.

1 INTRODUCTION

As on-site wastewater site assessors and system designers we work at the interface of end-users, regulators, technology suppliers, installers and servicing agents. This provides an insight into the operation, the politics, the strengths and weaknesses of a diverse community comprising the servers (essentially to regulators and industry) and the served (the end-users; the domestic home owner and the wider community). The on-site wastewater industry is an increasingly critical industry that is not only providing a key amenity service to a very large number of home dwellers in New Zealand (and always will), but is aiming to mitigate risks to public health and embedded ecosystems in a complex social, ecological and political environment. If we are to search for a common thread of purpose within this rather diverse on-site wastewater community, the underpinning philosophy of AS/NZS 1547 (Standards New Zealand, 2000) may be a good indicator (even though the interest of end-users was under represented in its formulation); namely *sustainable and effective on-site domestic wastewater management.*

In his keynote address to On-site 05 (Armidale), Ted Gardner explored the evidence for the sustainability of on-site wastewater systems (OWTS). He pointed out that despite the many reports of the high incidence on lot failure of on-site wastewater systems, evidence of off-site impacts ranged from *sparse to ambiguous* (Gardner, 2005). He then recommended monitoring at both the lot and the catchment scale, but only where it was established that the risks where clearly significant. At the same conference, Andrew Dakers advocated for the end-users by suggesting that a more sustainable and integrated on-site wastewater service could only be achieved by adopting a systems approach that not only engaged the policy makers, regulators and industry, but also the end-users as equal stakeholders (Dakers 2005). Both presentations emphasized the importance of the sustainability of on-site wastewater serving, one recommending risk based monitoring programmes and the other recommending a systems approach to achieve buy-in from all key stakeholders.

There is a growing concern in New Zealand about "failure" of OWTS and the risk such failures may impose on public health and local ecosystems. The recent Ministry for the Environment sponsored issues and options report (Duffill Watts & King et al, 2005) provided us with a vastly improved understanding of the issues concerning OWTS services in New Zealand, and recommended improved industry training, better access to information, improved commissioning and servicing of OWTS, performance monitoring and certification. While we would agree that these recommendations are important this and other key documents have been unconvincing in terms of the real and relative risks from on-site wastewater systems (including the co-called failed system). We are equally concerned that, to date, the importance of competent site assessment, system design and component resilience are understated and that end-user interests are over shadowed by policy and industry self-interest.

Within the New Zealand regulatory context of the Resource Management Act, monitoring and evaluation of OWTS has become required in several regions, depending on how well developed the regional planning process is. Monitoring and evaluation is seldom attempted, and when it has been on a trial basis, the results have been instructive of problems, either in the monitoring and evaluation process, in the onsite systems implemented, or both (Simonson 2009, Pers. Com 2009a). Even ensuring that compliance certificates are signed off to complete the installation process has not been effective to date (Pers. Com 2009a). Clearly there is a need to focus on how to carry out effective monitoring and evaluation of OWTS. Far from being a problem peculiar to New Zealand, it is recognized worldwide as a problem where OWTS have been installed. A quick search of Google produces "fact sheets" and research projects from around the globe attempting to address the problem (e.g. Corbett et al. 2002, Steer et al. 2002, Dallas et al. 2004, McQuillan 2004, Mbuligue 2004, HELCOM 2007, Renman et al. 2008, Koiv 2009).

Internationally, monitoring and evaluation of OWTS has been carried out under various regulatory frameworks and for various intentions. Usually it has been carried out as research projects rather than in an ongoing and comprehensive way for regulatory compliance. Such research projects have also been carried out within New Zealand. These are generally one off (for example Codlin and Peacock, 2007). Longer term, studies are limited, nevertheless, they provide a starting point from which to critically examine the monitoring and evaluation of OWTS performance and related risks. Here we outline, through a review of research literature, what issues have been addressed and what key findings relate to monitoring and evaluation of OWTS.. Recognising the under-representation of end-users' interests in previous studies, we also outline key findings from interviews that were undertaken with 20 end users (clients) of domestic OWTS in the Canterbury region during June and July 2009. The aim of the interviews was to provide a "snapshot" of the perspectives of end users on selection of OWTS, potential risks associated with wastewater systems, and the levels of service provided by the industry and regulators. Key findings from the interviews with end users suggest that future monitoring and evaluation of OWTS performance and risks would need to include some core areas of focus to ensure that the needs of clients and the wider community are being met. In addition, understanding the attitudes and behaviours of clients through monitoring and evaluation, is likely to contribute to the effective design, implementation, and sustainability of OWTS, as well as improving processes, and compliance regarding regulatory requirements.

Literature Review

The first question that needs to be addressed is the focus of monitoring and evaluation of OWTS undertaken in New Zealand and Internationally. Three key purposes are found in the research literature. One is the effect OWTS have within catchments to affect on public health and potable water (eg. Ray 2007, Corbett et al. 2002). A second is the effect of OWTS on streams, costal marine ecosystems and lake ecosystems (eg. Ray 2007, Harris 1995, Boesch 2006). A third is the effect of OWTS on greenhouse gas emissions (eg. Liikanen et al. 2006).

A question that is seldom asked, but from a management and regulatory perspective is crucial, is the relative benefits of monitoring and evaluating the effect of OWTS. The opportunity cost of monitoring and evaluating OWTS may be higher if the effort could be more effectively spent assessing non-OWTS effects on potable water within catchments, costal marine and lake ecosystems, and greenhouse emissions. For example the relative effect of OWTS compared to agricultural production practices (discussed in more detail later in this paper), including animal waste treatment systems, and centralized municipal wastewater treatment systems needs to be assessed. Consideration of how to most efficiently spend public funds is almost certain. Moreover, what is appropriate will be very dependent on the specific context. Key research projects whose results have been recorded in literature often begin by referring to a heavy density of OWTS at a particular setting (eg. Mc Quillan 2004, Clark 2005, Boesch 2006, Garrison et al. 2007). A preliminary discussion of the significance of the effects on potable water from OWTS is not merely a means by which to introduce the research topic, but is a necessary first step in clarifying any meaningful monitoring and evaluation process of OWTS, in any particular context.

Integrating science into management

To be able to address the impact of OWTS on potable water, an adequate management regime has to be in place. The consensus in the literature appears to be that effective management must seek to integrate science into management, and that adaptive management is the most effective way to do this (e.g. Boesch et al. 2006, Linkov et al. 2006, Manring and Moore 2006). Given this, key areas of concern arise, namely (i) the appropriate analysis of risk, including the communication of uncertainty, (ii) the resilience of treatment systems, and (iii) the various ecosystem states that can arise and what triggers change from one state to another. Another crucial issue that should be considered is the knowledge and perceptions of cklient as end-users of OWTS, and how their perceptions and subsequent behaviour impact on the resiliency of OWTS, and related risks.

Assessment of risk and resiliency

An appropriate assessment of risk has to address both the effect which is of concern, and to whom, and the relative uncertainty or frequency of it occurring. The product of these two values, when quantified, then enables the comparison of risks. This allows, for example, the relative significance of the effect of OWTS compared to other possible sources of pollution. The quantification used for these two values, is usually the probability of occurrence used to communicate the relative uncertainty or frequency of an event, and the cost in monetary terms dollars to communicate the magnitude of the effect. Analysis of this is underway but not yet well developed (Carroll et al. 2004, Clark 2005, Ascough et al. 2008).

The resilience of treatment systems is intrinsically related to the risk of incidents. The more resilient a treatment system is, the greater range of conditions can be dealt with successfully without incidents arising. It is crucial that assessment of resilience is carried out to ensure that the resilience of treatment system is appropriate for the conditions. There are tradeoffs, whereby greater resilience may come at an unnecessary cost to ensure stable conditions. To carry out analyses of resilience, modelling of the treatment systems and possible pathways for incidents is necessary and then optimized by comparing with predicted and actually monitored data (eg. NDWRCDP 2005, Dupuit et al. 2007). There are many sources of uncertainty and the communication of them often requires the use of expert judgment. Now through the concern for monitoring and evaluation of OWTS, the attempt has begun to develop data derived values of uncertainty where there is data from monitoring (Mouton 2009). Data derived from monitoring is found to be superior, indicating the value of long-term monitoring and evaluation programmes. But realistically expert judgment will always be necessary to some degree, especially during the initial stages of the evaluation of a system. There have not been many long term studies that enable resilience to be analyzed from data (eg. Mustafa et al. 2009). Most studies are snapshots of specific systems during the early stages of their implementation. These analyses provide insight but further long term research is required to provide data about the resilience of OWTS.

Monitoring and evaluation of ecosystem states and OWTS design

For the biological treatment systems (which is a predominant proves in most on-site treatment units) various ecosystem states arise, and the variety has a marked affects on the treatment processes. The different ecosystem states refer mainly to whether it is oxic or anoxic, or both; however there are also other significant typological features. For example substrate type and higher plant species composition. Design of biological OWTS revolves around ensuring that the appropriate and stable ecosystem state is created and that the planned state is resilient within the range of conditions making up the specific context. Failure to address this is what most commonly causes incidents of failure to occur in OWTS.

Research that has developed over recent years, now determines the different microbial groups that are operating in OWTS processes (eg. Fauletter et alet al. 2009). These groups relate to the chemical composition of substrates, as well as whether or not the system is oxic. Moreover they are affected by the other species in the ecosystem, especially higher plant species (Calheiros et al. 2009). Many analyses focus on the processes of nitrification of ammonia and then denitrification (eg. Schipper 1993, Willems 1997, Gill 2009). The contribution of these processes towards OWTS incidents is usually overlooked.

It is necessary to focus on both the affect of incidents and the uncertainty or frequency of incidents occurring when assessing their risk. Two issues arise when considering the affect and frequency of incidents: (a) what are the detrimental effects and beneficial effects from incidents, (b) what indicators are used for incidents in their early stages so that problems can be addressed quickly within an adaptive management process.

Monitoring and evaluation of the affects of OWTS incidents

The impact of nitrates on sensitive water bodies has been the focus of attention in New Zealand in recent years. (Elliot and Stroud 2000, Hamilton and Wilkins 2004, Hamilton 2004, Rutherford et al 2003). As a consequence two regional councils have been convinced that they should impose nitrate emission limits on domestic on-site wastewater system in ecologically sensitive zones (Fletcher 2007) One of the key reports often referred to in relation to the risk of on-site system to surface waters is the Elliot and Stroud (2001) report on nutrient loadings to Lake Taupo. This study used the computer model, GLEAMSHELL to determine the relative contribution of nutrient loads to Lake Taupo from the different land based activities. Their executive summary and results made no specific reference to the risk of nutrient contamination from on-site wastewater systems, but did refer to sewage runoff from a number of sewage treatment plants discharging to the lake (contributing 3% of the total nitrogen (TN) load to the lake). In evaluating the (TN) contribution from individual on-site wastewater systems, the authors assumed a total of 1435 "septic tanks" discharging annually 5kg and 1 kg of TN and total phosphorus (TP) respectively per person and they also assumed 5 persons per "septic tank". This would equate to 25kg/yr per septic tank. It is not clear from the report whether the model allowed for any attenuation of TN between the septic tank outlet and the entry point to Lake Taupo. Cleary the degree of attenuation would depend on the distance from the lake and the type and operational mode of the land application system post septic tank. A secondary or advanced treatment system to subsurface irrigation, handling 1000L/day (equivalent to 5-6 people), with effluent prior to an irrigation field at 40mg/L would apply 14.6 kg to the irrigation field/yr and after in-field plant uptake and denitrification, the leachable TN is likely to be less than 7 kg/yr. At the average national dwelling occupancy of 2.7, the average TN yield/dwelling reduces to about 3.8 kg TN per household. This is significantly less than the 25kg/yr that appears to have been used in the GLEAMSHELL model. Even at 25 kg/yr Elliot and Stroud concluded that TN contribution from on-site system was not significant. The relative risk from an annual TN load to a catchment of 3.8 kg/day nitrogen could be compared to that from the voided feaces and urine from domestic animals such as one Labrador sized dog (about 5 kg/yr), a horse (approximately 110 kg TN/yr) or a cow at about 90 kg TN/yr. Real and relative risk needs to be evaluated to determine common sense policy.

As with faecal coliforms phosphorus and nitrogen have been monitored as indicators of the total effect of incidents and hazards. For example, it is now recognised that nitrates are rarely a potential human health risk; only for bottle fed babies, and then only when there is simultaneously the presence of microbial pollution (Pers Com 2009b, Avery 1999, WHO 2007). So nitrate concentrations are often being used mainly as an indicator of other likely pollutant combinations, rather than evidence of itself as a pollutant. This begs the question as to whether or not nitrate concentration is an effective indicator for contamination. Given that potable water is usually obtained from groundwater, and nitrate concentrations under represent the pollution of anoxic groundwater, it is problematic even as an indicator (McQuillan 2004). Other indicators have been found to be superior, for example, chloride and silicates (Mc Quillan 2004, Corbett 2002). What can be safely concluded is that a real problem is the presence of microbial pathogens, of which faecal coliforms appear to be an adequate indicator.
There are real risks associated with the nitrogen cycle within OWTS processes. These do not appear to be primarily with nitrate, unless nitrate is also present with phosphorus at concentrations that lead to eutrophication of lake and coastal waster bodies (eg. Garrison et al 2007, Edwards and Withers 2006, Fedro et al 2008, Reopanichkul et al. 2009). But this phenomenon involves concentrations of nitrate which are not intrinsically related to those regulated against in potable water in a very risk averse way to safeguard human health. ammonia, even at low levels, is a problem where chlorination of potable water is carried out. The presence of ammonia inhibits the effectiveness of chlorination to kill microbial pathogens (van den Akker et al. 2008). Design for chlorinated potable water needs to ensure that

complete nitrification occurs. The denitrification process of removing nitrates produces potentially serious greenhouse gases far problematic than carbon dioxide, in particular, nitrous oxide (N_2O). The Global Warming Potential (GWP) of nitrous oxide is 310 (methane is 21 and carbon dioxide is 1). Nitrous oxide is only an intermediate phase to molecular nitrogen, but under certain conditions does concentrate. Various researchers have shown that N_2O production will be variable in biological wastewater treatment units and can result from denitrification processes under certain conditions (Thorn and Sorensson, 1996, Park et al. 2000). After the initial highlighting of the issue, further studies of nitrous oxide concentration have concluded that only about 2% of nitrogen is emitted as nitrous oxide and so is not a serious problem (Liikanen et al. 2006). But it does leave open the issue of whether or not there is any real benefit to be gained by ensuring that there is denitrification as well as nitrification. This is a significant design question as major design features revolve around whether or not denitrification is sought as well as nitrification (Obropta and Berry 2005, Healy et al. 2007, Renman et al. 2008, Gill et al. 2009). Such questions cannot be asked in isolation, out of a specific context. Synergies may occur to sometimes bring other context specific benefits and costs from denitrification. An example is that heavy metal removal is enhanced through denitrification, even if the removal of nitrate is not an issue (Blecken et al. 2009).

Monitoring and evaluation of the benefits of OWTS incidents

To complement the study of real risk associated with OWTS it is also necessary to consider the benefits to be gained from OWTS operation. In particular there is the opportunity for nutrient harvesting (Koskiaho et al. 2003). It has been suggested that a nutrient recovery market be established to promote this to be taken more seriously (Hey et al. 2005). It could be argued that denitrification is a loss of a valuable resource. More importantly, what should drive design is how to recover phosphorous. The well known Professor Emeritus of Civil Engineering, (University California, Davis), George Tchobanoglous, recently toured NZ (2008) and he referred to “peak phosphorous” and the risk high cost and scarcity of phosphorous presents globally to food security. Apart from nutrients in the wastewater stream the other resource is water. It is expected that within the next 50years more than 40% of the world population will be facing water scarcity (Metcalf and Eddy, 2007 p 179). This trend is contributing to the present focus in a number of countries on developing technologies, guidelines and regulations for the safe and economic reuse of the water component of the wastewater.

In the near future there is likely to be design criteria that recognize the resource value of wastewater rather than design to decrease nutrient emissions. In terms of sustainability, as well as clarity as to what the relevant technical design drivers are, some form of long to medium term cost-benefit analysis, including of opportunity costs, is necessary to ensure that public funds are used to bring the most benefit.

Monitoring and evaluation to prevent the occurrence of incidents

As well as the effect of incidents from OWTS, the uncertainty of their occurrence needs to be addressed. System failure generally occurs within the lot boundary. The incident impacts off site will depend of two key features. One is the transportation processes of wastewater, and the other the density of OWTS. Unlike other risk uncertainties, for example flooding, the sources of uncertainties in OWTS failure and incidents are not stochastic extreme events. It is now well understood that failure within the lot boundary will be due to one or more of the following; incompetent site and soil assessment; poor design, technology selection and siting; inadequate servicing and operation management. (Duffill Watts & King et al, 2005, Ray, 2007). As previously noted what has not been well evaluated is the real and relative risk of such ‘failures’ off-site (Gardner, 2005). What can assist in overcoming lack of understanding of the off-site risks are; better modelling of the transportation of effluent processes; the collection of more data to assess the effect of the density of OWTS that occurs;

data collection and analysis to assess the resilience of OWTS technologies, and; data collection and analysis to assess the fit between resiliency factors and regulatory requirements.

Monitoring and evaluation to improve transportation of effluent, density of OWTS, and resiliency

Improving modelling of transportation processes and the collection of data on the effect of density of OWTS has been a key focus of research to date. For example, recently it has been found that effluent transportation in the semi-saturated zone is horizontal as well as vertical, which means that setback distances need to be greater than what have previously modeled to be necessary (Heatwole and McCray 2007). This agrees with other empirical studies of pollution from OWTS (Abit 2008). What has largely remained overlooked has been the study of the resilience of OWTS technologies and systems. Even though there are studies on the resilience of water network systems (eg. Milman and Short 2008, Zhang et al. 2009), there does not yet appear to be research literature to guide the effective design of resilient OWTS. The danger of this situation is that it can potentially lead to the wrong presumption that a scaled down version of what is resilient in municipal systems applies to OWTS. There are scale effects in how ecosystems operate to suggest that scaling down of design resilience might not be appropriate For example, aerated OWTS systems would need decreases in the degree of fluctuation of influent levels to be at the same rate as the scaling down in size from municipal waste water treatment systems to OWTS. To avoid this, relatively more resilient ecosystem design would be needed for OWST compared to municipal systems. To date this has usually been assumed to be limited to microbial communities (eg. Tiedje 2001, Briones and Raskin 2003). There is no intrinsic reason why wastewater treatments should be restricted to microbial communities, other than designs of wastewater systems that have mainly been limited to utilizing only microorganisms. Designing OWTS to include greater diversity through higher species trophic levels of species can be expected to further increase resilience. The high levels of treatment provided by engineered wetlands and peat bed and topsoil indicate this. Vermiculture designs offer another way to do this, as do aquaculture designs (Yan et al. 1998, Viva et al. 2009).

Monitoring and evaluation to inform OWTS R&D and design for specific contexts

The issue of resilience of OWTS design is a pressing issue for another very practical reason, which is that many OWTS systems are now off-the-shelf manufactured systems. The significance of the specific context for the OWTS design is often overlooked. So, to the extent OWTS remain generic manufactured designs, the resilience of the design to the effect of the variable contexts in which they are imbedded is crucial. Otherwise a risky ad hoc situation arises. There are of course two ways in which to address this issue. One is to ensure the resilience of generic manufactured designs, and the other is to rely on context specific designed systems. The latter approach, though perhaps being the technically simpler, is more complicated for the regulator. Some sort of cost-benefit analysis of the two approaches is required, with surely some balance of the two being appropriate depending on the regulatory, business, and geographical context.

To date, regulators focus on “approved” treatment technologies and compliant discharge fields. Planners and policy advisers are beginning to use data analyses for assessing relative risks of OWTS densities and contaminant transportation processes. Where there is scope for improvement is to consider the resilience of the design not only of discharge fields but also of prior treatment unit. To do so some clarity is first required as to the appropriate indicators and what should drive the design process. At present in New Zealand, the focus is on the testing and national certification of manufactured package units with effluent nitrate levels remaining a key performance criterion. (Lavery et al 2007). From the review of literature carried out above, the significance effluent nitrate levels is, in our view, overstated for most settings.

What is required is public good scientific research of appropriate and resilient on-site wastewater technologies, treatment processes and management systems in parallel with real and relative risk based performance standards and a thorough study and development of the appropriate monitoring indicators. Only when this is completed will it be possible for OWTS to become more integrated, innovative with more appropriate designs. Furthermore regulators can then be confident that designers and manufacturers are providing the best designs for the end-users. Otherwise, regulators will continue to approve only manufactured technologies and system designs that have been tested and evaluated in unreal contexts.

Meeting the needs of end-users and communities

According to the recent Ministry for the Environment study, twenty percent of homes in NZ rely on on-site wastewater service. (Duffill Watts & King et al, 2005). This is a significant infrastructural service providing to a very large number of New Zealand citizens. Monitoring and evaluation of OWTS needs improvement to ensure that end-user 'needs' are well represented. It is our view that this is not the present case. Much of the shaping of on-site wastewater policy, rules, and standards, R&D, is predominantly driven by industry and regulators. As mentioned, research focuses on the effects of OWTS on the biophysical environment of catchments, providing potable water, coastal ecosystems and greenhouse gas emissions. Equally important, however, is how effective they are providing for the specific amenity needs of clients. Within the New Zealand context, this is also a regulatory responsibility, as the effect on individuals and communities has to be taken into account (MfE 2008). Moreover, most significant definitions of sustainable development also require an appreciation of end users needs (Morrison and Singh 2009).

It is of not only the wellbeing of a particular paying end-user that has to be designed for, monitored and evaluated, but the well-being of end-users generally and the whole community they belong to. The professional code of ethics of the New Zealand Institute of Professional Engineers (IPENZ) formulates this well (IPENZ 2007). The IPENZ code states that the wellbeing of the society as a whole and the environment as a whole has to take precedence over any particular paying end-user, but that end-users still take precedence over the professionals providing the service. The IPENZ code states very clearly that design is to serve end-users as well as the wider society and environmental well-being. This needs to be central to any monitoring and evaluation process of OWTS.

To inform this paper, interviews with 20 end-users of domestic OWTS in the Canterbury region took place during June and July 2009. The aim of the interviews was to provide a "snapshot" of the perspectives of end-users on selection of OWTS, potential risks associated with wastewater systems, and the levels of service provided by the industry and regulators. The methodology used and its limitations, and key findings from the interviews with end-users are set out below

Key findings from interviews with end-users in Canterbury

Key findings from the interviews with end users suggest that future monitoring and evaluation of OWTS performance and risks would need to include some core areas of focus to ensure that the needs of clients and the wider community are being met. Core areas of focus could be in relation to (but not limited to): clients knowledge and understanding of: the types of OWTS available and their performance features and coinciding regulatory requirements, as well as perceived and actual risks from OWTS and ways to minimise risks Furthermore, criteria regarding clients perceptions of the level of services provided by the industry and regulators and ways services could be improved.

Methodology and limitations

The process followed to complete the interviews for reporting purposes was as follows:

- 20 end-users that were randomly selected from an existing end-user database of around 100 end-users, were asked if they would be happy to participate in an anonymous 10-15 minute interview with Social Foci, as an independent research company.
- On completion of interviews, interview transcripts were transcribed and provided to interviewees to make any additions, or changes to the interview transcript.
- Once interview transcripts were modified according to interviewee feedback, a general thematic analysis of the 20 interview transcripts was undertaken.

Since this research provides a "snapshot' of 20 end-users in the Canterbury region, there may be a number of additional factors relating to the selection of wastewater systems, perceived risks, and levels of service provided by the industry and regulators that are absent from the report. In addition, the interviewees are likely to include people who may have a higher ecological awareness, due to the fact that each chose to work with an eco engineer for advice and support in the design and/or implementation of their system[1]. , these findings can offer a useful framework for further research that aims to investigate, monitor, or evaluate perceptions of end-users of wastewater systems across New Zealand.

Summary of key findings

The key findings from interviews with 20 clients of OWTS are summarised under the headings below. The headings suggest core areas for future monitoring and evaluation to help ensure that end users needs are being met. Understanding the attitudes and behaviours of clients through monitoring and evaluation, is likely to contribute to the effective design, implementation, and sustainability of OWTS, as well as improving processes, and compliance regarding regulatory requirements.

Monitoring and evaluation of the level of end-user's knowledge about OWTS

Key findings show that end-users have little knowledge about the OWTS systems that are available, and how they operate. When asked about how levels of service could be improved by regulators to improve their knowledge, and subsequent decision-making in their selection of OWTS, end-users reported that:

- During the selection process, end-users would like to be able to contact regulators for independent advice regarding specific information about the variety of OWTS available, how they work, and ways to operate systems to ensure their sustainability. This would enable end-users to be better informed before contact is made with companies who sell OWTS.
- End-users would also like to access clear information about regulations and how they link back to specific types of OWTS.
- One end-user suggested that information about OWTS could be provided and set out in a similar way to the New Zealand "Consumer Magazine", which makes comparisons between products, including information about specifications, performance features, costs, and maintenance.

When asked about how levels of service could be improved by the industry to improve their knowledge and subsequent decision-making during the selection process, end-users reported that:

- End-users need more advice from the industry about the various types of OWTS, as end-users sometimes select the systems that are better advertised, but not necessarily best suited for their needs.

[1] Ecological Engineering offers an ecosystems approach, (systems thinking, ecology and self design/management) to the engineered projects within our society. This not only requires an understanding of, and integration with, the natural ecosystem within which the engineered project is embedded but also the social and cultural system.

- Case study examples of non-mainstream, more innovative OWTS could be provided to end-users alongside information about different OWTS.
- Providing information about the range of systems and their particular features (e.g. water quality output) would help to avoid confusion caused by conflicting advice provided to end-users by the industry.
- Showing the entire range of OWTS on the internet and their comparative performance features and cost would allow end-users to weigh up their choices for a wastewater system, without any influence from companies promoting their particular OWTS.
- Most end-users do not have the technical experience to make complex design decisions to meet regulatory requirements.
- Employing an engineer for a site assessment before selecting an OWTS can provide many benefits to end-users. For example, end-users find that by working with an experienced engineer they can explore more innovative options for a wastewater system, and select the best system for the layout of their property. End-users were also in a better position to meet regulatory requirements.

Monitoring and evaluation of OWTS performance features that end-user's want

When asked about performance features that they want in an OWTS end-users reported that they wanted an OWTS that:

- Has a proven track record.
- Is known by regulators.
- Has no noise, or minimal noise output.
- Is odourless.
- Is fairly compact and visually appealing.
- Has functions to detect wastewater overflow.
- Uses no electricity, or minimal electricity (and can operate after a power cut.
- Has minimal mechanical parts (e.g. has fewer, or no pumps)
- Is easy to maintain and requires minimal maintenance.
- Can use solar energy or wind power.
- Is resilient (e.g. can cope with everyday cleaners).
- Output water is clean enough standard to be able to use water for irrigation.

Monitoring and evaluation of end-users understanding and experience of potential risks from OWTS

When asked about potential environmental or health risks from OWTS, key findings suggest that:

- End-users only identified sewage overflow and odour from OWTS as key health and environmental risks.
- Of those end-users who had had their OWTS implemented (12 out of 20), none reported experiencing sewage overflow, or odour from their OWTS.
- , sometimes there is conflicting advice within the industry (e.g. from plumbers and wastewater companies) about the level of quality of water from an OWTS, and the appropriate use of that water.
- In general, end-users appeared to be aware of how to minimize health and environmental risks from their own wastewater system.
- The criteria provided by Environment Canterbury to end-users to help prevent health and environmental risks appeared to be a useful guide for end-users.

Monitoring and evaluation of service delivery in installation of OWTS

Key findings show that end-user's would like to be assured that installers of OWTS have experience in installing OWTS, and are suitably certified. When asked about how levels of service could be improved by the industry in this area, end-users indicated that:

- Communication between companies (and installers) and end-users is important, since problems with installations can arise from poor communications and misunderstandings. The industry could communicate better with end-users, and focus on what is important to end-users.
- End-users need to provide clear written briefs to contractors, or sub contractors that install OWTS, to ensure that systems are effectively implemented. The availability of contractors or subcontractors that need to work alongside each other to get an OWTS implemented also needs to be considered to avoid delays in installation
- Information about the capabilities of installers and their previous work experience, in installing specific types of wastewater systems, needs to be made available for end-users. Certification for people who install OWTS could be an option used, to ensure that installers are competent.
- Some end-users would like to be more involved in the installation process, or even to complete various stages of installation work on their own (to regulatory specifications).

Monitoring and evaluation to ensure resiliency of OWTS

Key findings show that end-users generally want OWTS that have less mechanical parts, and that require less ongoing maintenance. When asked about how levels of service could be improved by the industry in this area, end-users indicated that:

- End-users require more knowledge about the ongoing costs of maintaining OWTS..
- Generally, end-users want OWTS that have less mechanical parts, and that require less ongoing maintenance.
- One end-user felt that unrealistic expectations are put on end-users in regard to the frequency of tasks they have to complete to maintain OWTS (e.g. frequency of flushing pipes and cleaning filters). It was perceived by the end-user that most people were not likely to maintain their system at suggested levels.
- One end-user suggested that they would have liked to have contact with the company that they brought the system from once it had been installed, to check if the OWTS was implemented effectively and running well.

Monitoring and evaluation of the consent process and regulations

When asked about their experiences and knowledge of the consent process, it was found that:

- The consent process for sign off for implementation of OWTS is a key point of frustration for end-users.
- End-users find it difficult to access information about what is required for the consent process, and the time implications that are attached to the process. For example, the timing for getting a consent process started, if the process coincides with planning for a dwelling on the property.
- Simple guidelines about getting resource consents, timing requirements, and the order of what actions end-users need to take during the consent process could assist and benefit end-users.
- End-users were generally disappointed at costs incurred during the consent process. Regulators are could be more transparent about the costs associated with the overall consent process.
- There was a suggestion by one end-user that the consent process could be improved if end-users only had to only work through one regulatory body to meet compliance. The end-user had been sent back and forth from one regulator (Environment Canterbury) to the other (District Council) a number of times in trying to get compliance.
- There appears to be a lack of knowledge by regulators about the range of OWTS available and their performance features and functions, especially ones that are not necessarily in the mainstream market. This lack of knowledge appears to be a factor in delaying the consent process for some end-users.

- Regulations about OWTS and the design of available OWTS do not appear to meet the essential needs of some end-users. For example, one end-user who lives on a property in an isolated area was required to replace the septic tanks on the property with wastewater systems that run off electricity. To the end-user, this was not an ideal situation because the power supply is more likely to be cut off in rural areas, for longer periods of time.
- It may not be appropriate to apply certain standard regulations to all end-users, due to the diversity of land, including soil types and drainage, within regions.
- Additional support for the consent process by a qualified advisor, such as an ecological engineer is very beneficial to end-users especially if a site visit is undertaken at an early stage in the consent process.
- Having support from a qualified advisor tends to make the consent process easier and quicker for end-users, and helps to ensure that costs related to the consent process are more transparent.
- Checking the credibility of an advisor is important. One option suggested by end-users is that regulators should provide end-users with a list of competent advisors, such as ecological engineers.
- One end-user suggested that in the situation where a end-user has an OWTS that is known to be performing well, and where there has been input and some oversight from a competent and licensed engineer, regulators should not need to inspect OWTS as frequently.

2 CONCLUSIONS

If we are to return to the common (agreed?) objective of the on-site wastewater community referred to in our introduction, i.e *sustainable and effective on-site domestic wastewater management.* (Standards New Zealand, 2000), both our literature review and the survey of end-users has highlighted pathways by which the on-site water service can become more effective and more sustainable.

With a principled monitoring and evaluation process that takes into account both end-users and regulatory concerns, sustainable development can be sought to be enhanced through the use of OWTS. There clearly are problems with OWTS, from the point of view of both end-users and regulators. What the problems are are very different and to an extent complementary.

End-users voice the view that there is overregulation leading to unnecessary compliance costs and unnecessary hindrances put on the style of OWTS implemented. In stark contrast to this, the scientific literature suggests that the opposite appears to be the case. The severity of problem of OWTS for both human and wider ecosystems health is only now becoming better understood. What is common to these divergent views is the focus on the need to consider the specific context of an OWTS. It is possible that end-users may not experience being over-regulated, and the technical problems of OWTS could be addressed if there was more scope for innovative design to suit their particular contextual requirements, but this would most likely come at a cost for end-users.

More explicit incorporation of the specific context of an OWTS would mean that the OWTS would need to be designed by competently trained engineers who keep up with the scientific research that is still very exploratory. This would make it difficult for manufacturers to produce off-the-shelf systems, and so the production cost of systems is likely to be higher. Moreover, regulators would be less able to rely on blanket prescreening approval of generic manufactured designs for “permitted activities”, and so need to become more highly trained in analyzing the potential environmental effects. In short there would most likely be an increased need for resource consent\ applications. This can be expected to increase the cost of compliance to end-users rather than to decrease it.

The way forward has already been voiced in the literature. It is to improve risk communication and to implement adaptive management. All players, end-users, planners, regulators, designers and industry need to become more aware of the real risks of OWTS so that they can gain a realistic grasp of their appropriate role and responsibilities and the challenges and costs involved in designing a safe OWTS. , an explicit focus on adaptive management where there is collegial interaction and ongoing mutual learning between design engineers, manufacturer and regulators would enable better practice to become developed most efficiently. If there was simultaneously attentiveness to end-users' needs and concerns, which were explicitly incorporated into the adaptive management process, progress may develop more quickly.

The need for far greater dialogue and interactive social learning between designers, manufacturers and regulators to clarify what the tradeoffs are so that public funds are most effectively used and end-users are treated fairly. Analysis of the relative risks of the various polluter sectors needs to be carried out to ensure equitable burdens are placed on end-users and also that public funds are used most effectively to mitigate the effects of pollution. This need to be carried out and communicated in a transparent way so that end-users feel that they can trust the regulators. To start the process will require the establishment of explicit monitoring and evaluation processes to effectively assess and improve OWTS, and to help guide the necessary competences of engineers designing OWTS.

ACKNOWLEDGEMENTS

Diana Edwards for many hours of transcribing. All the **ecoEng clients** who willingly participated in the survey.

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