Impact of on site sewage treatment systems on river water quality in UK catchments

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Abstract

Until recently, the impact of effluent discharges from on-site waste water treatment systems (STS) within the UK was believed to be negligible. This was mainly because the number of systems was unknown. When a range of different methods were used to estimate the number and location of STS more accurately, it was found that the number of consented systems was probably less than 10% of the total number of systems in many areas and registration schemes were introduced. At the site specific level, that discharges from these systems can have a high impact on downstream water quality can be high. In-stream phosphorus (P) concentrations can be up to four times higher downstream of STS than upstream. At the catchment scale, the likely impact of STS on downstream water quality is usually estimated from information on consented STS, only. When all STS are taken into account, estimated contributions from agricultural sources may be up to 20% lower than previously thought.

Keywords: on site sewage treatment systems, septic tanks, phosphorus

Introduction

Until recently, discharges from on-site waste water treatment systems (STS) and other small rural sources of nutrient export to nearby water courses had rarely been documented within the UK. Indeed, there was a widely held belief that septic tanks were not a problem, especially at the landscape scale. However, mounting anecdotal evidence is emerging to suggest that these sources may be causing water quality problems and warranted closer investigation.

In 2010, during a project funded by Natural England, May et al. (unpublished) compiled a wide range of case studies that supported this assertion. Many of these are summarised below. Some provide evidence of direct discharge whilst others show that exceptionally large discharges from such sources may be driven by high rainfall events. This is an important observation because this type of event is often missed by routine monitoring and may become increasingly common with climate change. Other case studies from across Europe, but not documented here, also provide evidence of the potentially large impacts that STS can have on water quality in rural headwater streams, especially during the ecologically-sentive low flow conditions (Withers et al., 2012).

Number and location of septic systems within the UK

There are an estimated 1.4 million STS across the UK, many of which are very close to watercourses. Most discharge to a soakaway, but some discharge directly to water *via* a discharge pipe or drainage ditch. In spite of their large numbers, the exact locations of STS across the UK are, for the most part, unknown.

In recent years many different methods have been used to derive their numbers and locations from existing datasets. Some of these are described below.

Postcode method: One method that has been used to estimate the number and location of STS is the 'postcode' method, which was originally developed and applied to the catchment of Bassenthwaite Lake (May et al., 1999). This method involves removing dwellings that are connected to mains sewerage systems from a 'master' list of all dwellings in an area, making the assumption that the remainder are served by STS. This method has potential for widespread use over large geographical areas if appropriate data on sewer connections are available. For example, it has been used to approximately locate septic tanks within the catchment of Loch Leven, Scotland, (Dudley *et al*., 2007) and across the whole of Scotland (SNIFFER, 20068).

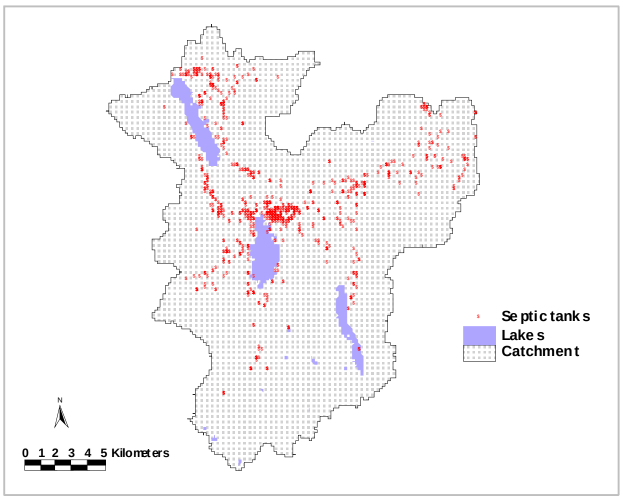

Fig. 1. Estimated location of septic tanks within in the catchment of Bassenthwaite Lake *(after May et al., 1999).*

Sewerage network method: Another method of estimating the number of septic tanks is described by Hilton *et al*., unpublished. This involves using sewer system network diagrams to derive the area of a catchment that is served by the mains sewerage system. The method assumes that premises that are outside sewered areas are connected to STS. Although effective, this method is difficult to use in practice because utility companies may be unwilling to disclose the necessary information about their sewer networks because of its commercial value and security implications. Also, it cannot necessarily be assumed that all properties within an area served by a mains sewerage system are connected to that system.

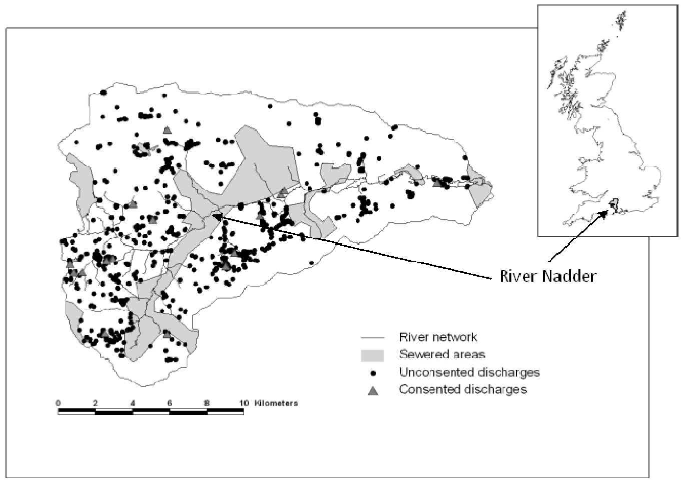

Fig. 2. The catchment of the River Nadder, Wiltshire, showing sewered areas, and consented and unconsented STS (*After Withers et al., 2012*).

Aerial photography method: May et al. (unpublished) derived the number and position of STS within their study catchments from aerial photography. Each 'house' was digitised from the aerial photography using Erdas Imagine® and the authors made the assumption that residential properties ('houses') that were within these rural areas but beyond the area served by a mains sewerage network were had STS.

The location of these unsewered 'houses' in the River Nadder catchment is compared to the number consented STS discharges in Figure 2. Overall it was found that less than 1% of STS in this area were consented. A similar pattern emerged from studies undertaken in three other rural catchments.

Local knowledge method: For small catchments, STS can be located by harnessing local knowledge. This method has been used to locate STS within the catchment of Loweswater, Cumbria (Maberly *et al*., 2006; Figure 3) and in the River Clun catchment, Shropshire (Fildes, 2011). However, this method is not practical for application to large catchments that cover a wide area.

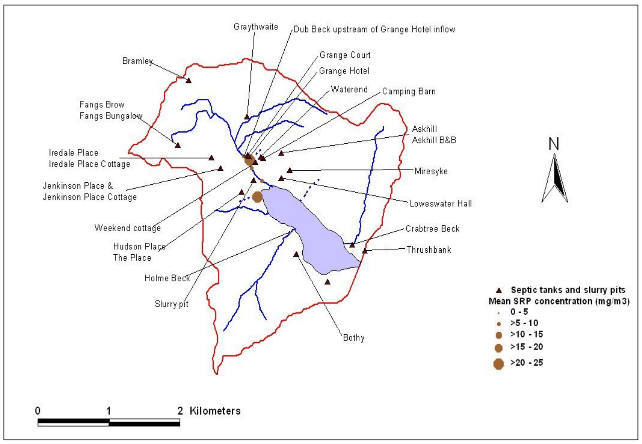

Fig. 3. Location of septic tanks within in the Loweswater catchment based on local knowledge (*after Maberly et al., 2006*).

Large area statistics method: A recent re-analysis of data compiled by Faber Mausell (2003), Anthony et al. (2006) and Stapleton et al. (2006), has shown that, at the larger scale, the approximate number of STS in any given area can also be derived from nationally available datasets (Anthony, *pers. comm*.). The data used in this study comprised:

1. *For Northern Ireland*: information on septic tanks usage from 1991 population census returns
2. *For Scotland*: properties located within Postcode Sectors across Scotland, as derived from an OS Address Point database, and outside of a sewered area
3. *For North West England*: information on properties known to be using septic tanks from local water company data

These analyses were performed at district council and postcode sector level and the relationship between property density and percentage connection has not been validated for application elsewhere.

Although there are large uncertainties within these data, a clear relationship was found between the percentage of properties that are not connected to mains sewerage systems and the density of properties (Figure 4). Although this method does not provide details of the exact locations of individual properties and is probably too coarse for application at a site or catchment specific scale, it does provide a way of estimating the number of properties that are served by STS at the regional or national scale.

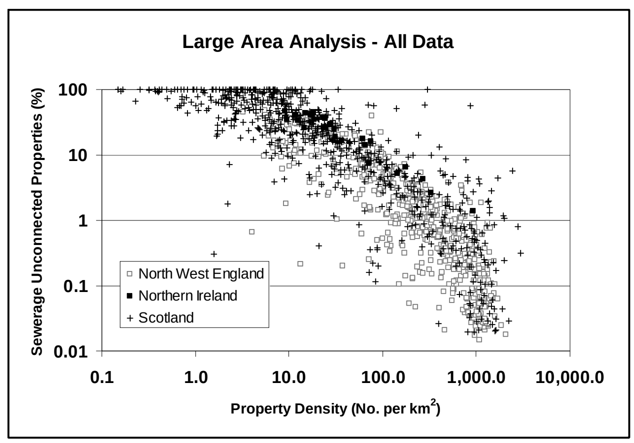

Fig. 4 Relationship between the percentage of properties using STS and the density of properties in a given area (*After Anthony, pers. comm.., ADAS UK Ltd*.).

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Improved registration: Under the Control of Pollution Act 1974 (CoPA) all sewage discharges to surface waters in Scotland required consent from the Scottish Environment Protection Agency (SEPA). However, in most cases, there was no requirement to obtain consent for STS discharges to soakaway. This led to incomplete records of septic tank locations. Since 1 April 2006, there have been significant changes to the control of sewage discharges following the introduction of the Controlled Activity Regulations 2005 (or CAR). Under these new regulations, all new STS discharges from domestic properties serving less than or equal to a population equivalent (PE) of 15 are required register with SEPA. For population equivalents greater than 15, a discharge licence is required. Although SEPA discourages direct sewage discharges to waterbodies, where this is unavoidable these must also be registered.

A recent change to legislation within Scotland aims to address the problem of unconsented discharges retrospectively at the national scale. Since April 2006, all septic tanks must be registered with the Scottish Environment Protection Agency (SEPA) when properties change ownership. Over time, this will create a record of the size, location and discharge of all septic tanks in Scotland (SEPA, 2006).

A STS registration process was later extended to England and Wales as a result of new regulations introduced by the Department for Environment, Food and Rural Affairs (Defra) and the Welsh Government to meet the legal obligations imposed by the European Union Water Framework Directive. However, subsequently, compulsory registration has been suspended in England pending the outcome of a review of the need for such legislation. This is currently being undertaken by the Environment Agency and Government. In contrast to the situation in England, compulsory registration continues in both Scotland and Wales.

Impacts of STS discharges on water quality

The impacts of STS discharges on water quality at the catchment scale can be demonstrated by the results from a wide range of studies. Such studies include upstream and downstream water quality monitoring and catchment 'hotspot' surveys. Examples of the type of evidence collected is summarised below.

Eye Brook: The first example is part of a study on the Eye Brook, Leicestershire (Withers et al., 2011). Samples were taken upstream and downstream of two STS locations within the catchment, Village East and Loddington North, October 2006 to October 2007. In general, median soluble reactive phosphorus (SRP) concentrations were found to be three to four times higher downstream of STS locations than upstream, while median total phosphorus (TP) concentrations were approximately double upstream of these locations where farming was the only source of P (Figure 5). The results of this study show that STS can affect water quality in rural areas, especially if the effluent is being discharged directly into a stream. The results suggest that many STS are acting as direct point source inputs to headwater streams where there is very low dilution capacity. This causes degradation in water quality. The authors concluded that failure to take account of nutrient emissions from STS may undermine attempts to improve the ecological status of freshwaters by focusing control measures on major sewage treatment works and agriculture.

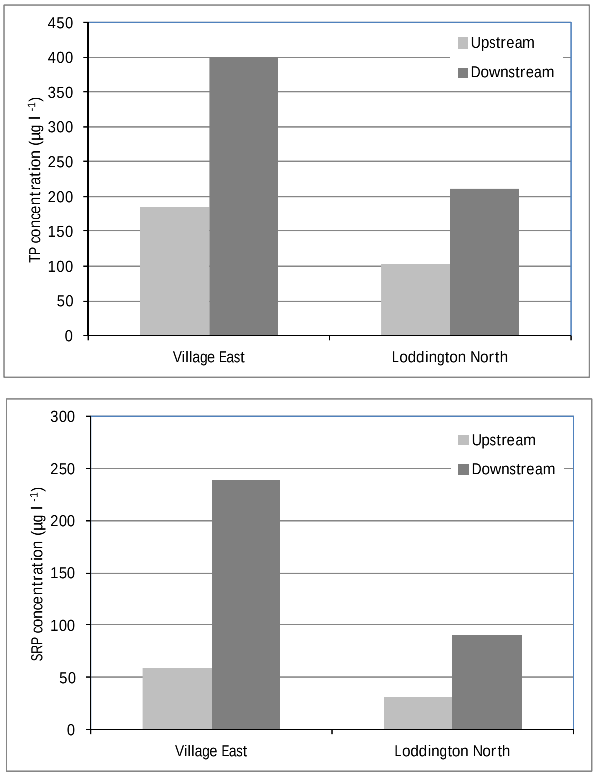

Fig. 5 Median concentrations in total phosphorus (TP) and soluble reactive phosphorus (SRP) upstream and downstream of STS discharges at (a) Village East and (b) Loddington North.

River Wyre: The second example is from a study of the River Wyre catchment, Lancashire (Nicholson, 2007). This study aimed to determine whether septic tanks contributed to SRP concentrations and loads in a stream that ran close to a small cluster of houses served by a STS. By measuring flows and concentrations along this stretch of the stream, the author was able to detect a marked increase in P concentrations and loads downstream of the STS, which was between sampling sites 4 and 5 (Figure 6). In-stream concentrations rose from about 50µg P l^{-1} to about 400µg P l^{-1} over a distance of less than 100 m. As there were few other possible sources of P in this area, it was concluded that the sudden increase in P in the stream was attributable to STS discharges.

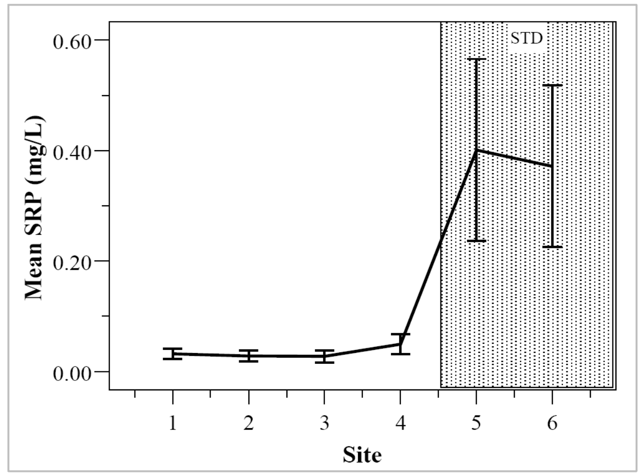

Fig. 6 Mean SRP concentrations along a short stretch of river within the Wyre catchment showing a marked increase between sites 4 and 5 (*After Nicholson, 2007*).

Loweswater: The third example is from a small feeder stream that flows into Loweswater, Cumbria (Figure 7). Here, OP concentrations were monitored from October 2004 to September 2005 (Maberly *et al*., 2006). Although annual mean OP concentrations in most of the inflows to the lake were low (i.e. < 10 µg P l^{-1}), this stream had a much higher OP concentration (i.e. ~ 24 µg P l^{-1}). Further investigation showed that the stream was receiving effluent from a faulty septic tank.

When combined with stream discharge rates, the mean daily OP load from this tank over the whole year was estimated to be approximately 8 g P d^{-1} or 2.9 kg P y^{-1}. However, during a storm event in December 2004, a single value of 122 g P d^{-1} (i.e. about 4% of the annual P load) was recorded. This highlights the importance of rainfall driven discharge events in delivering nutrients to watercourses from some STS. In this case, this was a STS of outdated design that received roof runoff as well as sewage and, therefore, tended to overflow during heavy rainfall.

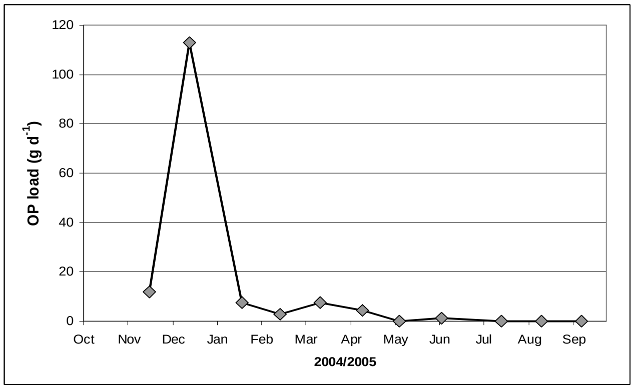

Fig. 7 Seasonal changes in orthophosphate (OP) loads in a small inflow to Loweswater in 2004/2005 (*After Maberly et al., 2006*)

Hornsea Mere: Pollution impacts of STS at a wider spatial scale can be assessed by 'catchment walks', whereby samples are collected at a range of sites over a wide area to identify 'Hotspots' where phosphorus concentrations are high (e.g. Withers et al., 2009).

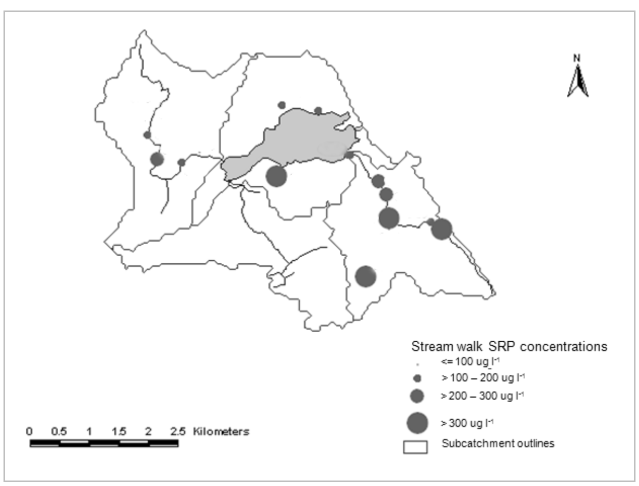

Fig. 8 Orthophosphate concentrations (µg P l^{-1}) within the catchment of Hornsea Mere (*After May et al., 2010*).

This type of survey was undertaken across the catchment of Hornsea Mere, Yorkshire by May et al. (2010). Orthophosphate (OP) concentrations were found to be very high in many locations, with values of 200 µg P l^{-1} to 300 µg P l^{-1} commonly recorded just downstream of known STS (Figure 8). An exceptionally high value of more than 2 mg P l^{-1} was recorded just downstream of one particular STS. This study demonstrates how widespread P pollution from STS may be in some rural areas.

Blackwater River: In addition to evidence at the site specific level, outlined above, Arnscheidt *et al*. (2007) showed that the impact of STS discharges on water quality can also be detected at the catchment scale. Their study involved a survey of the STS in three rural tributaries of the Blackwater River, Northern Ireland, together with high frequency (10 minute intervals) monitoring of TP concentrations at the catchment outlets.

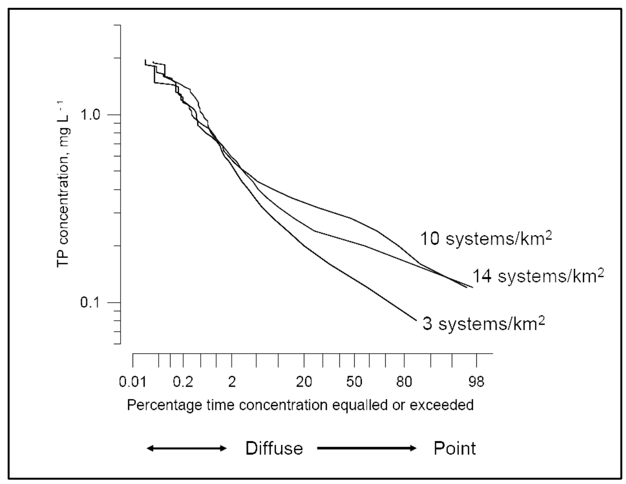

Fig. 9 Percentage of time in which the total phosphorus (TP) concentration in three streams at each catchment outlet was greater than or equal to a given threshold concentration (y-axis) in comparison to the upstream density of STS (*After Arnscheidt et al., 2007*).

Arnscheidt *et al*. (2007) showed that a range of threshold TP concentrations were exceeded more frequently in catchments with higher densities of STS than those with lower densities (Figure 9). They also found that more than 60% of these tanks were at high risk of causing water pollution because of their condition, management and location.

Estimating P losses from STS to water at the catchment scale

It is relatively easy to estimate the amount of P that enters STS from domestic waste. However, it is much more difficult to determine the amount of P that is ultimately discharged into the environment after processing within the tank and retention within the drainage field. This is because there are few measured values and the level of discharge from a given system depends on a range of local environmental condition (May et al., unpublished).

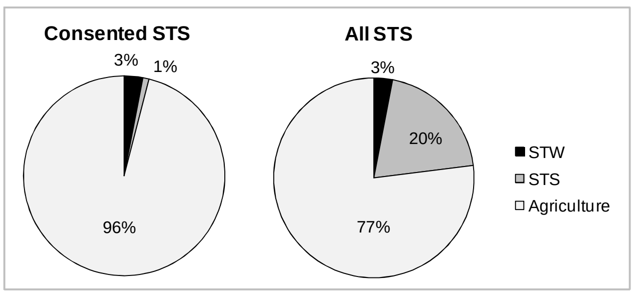

Fig. 10 Source apportionment (%) of the total P load in the River Bure, without and with unconsented STS. P sources are: sewage treatment works (STW), on site waste water treatment systems (STS) and agriculture.

Nevertheless, one of the greatest uncertainties in the estimation of P losses to water at the catchment scale is the number of STS (Withers et al., 2012). Using case studies from the Norfolk Broads and Hampshire Avon, May et al. (unpublished) demonstrated that existing records of STS in many areas reflected less than 10% of the actual number of tanks. So, it was concluded that most estimates of the amount of TP emanating from these systems at the catchment scale was probably less than 10% of the actual value. Using this information and applying a simple *per capita* export coefficient approach, the authors compared estimated TP outputs from consented STS within several rural catchments with those from all STS within those catchments.

The results were used for the source apportionment of TP within the receiving rivers. If all STS were taken into account, the amount of TP in the receiving waters that was estimated to be coming from agricultural sources appeared to be up to 20% less than if consented STS, only, were taken into consideration (Figure 10).

Discussion and Conclusions

The number of STS across the UK has been significantly underestimated in the past. Recent studies have suggested that, if all STS are taken into account, P discharges from these sources may have a significant impact on downstream water quality. Also, when the total number of STS is used in source apportionment calculations, the apparent P input to the drainage system from agricultural sources may be reduced by up to 20%. This provides an important insight into where mitigation measures should be focused.

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Acknowledgments

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