Siltation in SUDS – Myth and Reality

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1. Introduction

The vast majority of SUDS, whether "hard" or "soft", do not seem to suffer from problems with excessive silt accumulation if they apply the key concepts of the SUDS philosophy, ie source control with a correctly designed treatment train.

Examples include:

1. Hopwood Park MSA where a filter strip leading to a filter drain has not required silt removal during 8 years operation draining a lorry park and there is no evidence of serious silt accumulation.
2. Drainage to a sports centre in USA has had no maintenance for 12 years and silt accumulation is only apparent in inlets to bioretention areas. Volumes are not excessive
3. A pond at the Dunfermline Eastern Expansion where the results of measuring silt accumulation suggest that silt accumulation is not significant except during construction activities within the catchment.
4. Numerous pervious pavement systems that continue to operate despite silt accumulation and reduced surface infiltration rates.

Conversely some SUDS can understandably exhibit large volumes of silt accumulation where the system serves a catchment with a high volume of silt in the runoff. So is silt a problem in SUDS? Let us look at the facts.

2. Why is silt important?

Removal of silt from stormwater runoff is important because a large proportion of pollutants are attached to the silt particles. If the silt is removed then most of the pollution will be dealt with. Thus retention of silt in the SUDS is one of the prime objectives and should not be seen as a problem. If siltation is occurring the SUDS is doing its job correctly, whether it is a swale, a pond, a permeable pavement or a plastic tank system.

In fact designing a system to allow silt to pass through is more of a problem and does not meet the requirements of the SUDS philosophy. The key is to allow for the presence of the silt in the design of the SUDS and this is easily done. It is necessary to understand where the silt will collect within the SUDS and in what volumes. This allows design and maintenance so that it does not become a problem and prevent the system working as anticipated.

3. Silt loading

A study by Walker et al (1999) found the majority of sediment-bound contaminants was associated with the fine particle size fraction. Higher concentrations of pollutants such as heavy metals were associated with the smallest particle size fraction. The data indicated that almost half of the heavy metals (copper, lead and zinc) found on sediments were associated with particles of 60µm to 200 µm in size (ie fine sand size) and the majority (75%) were associated with particles finer than 500 µm in size. This is the material that needs to be captured in the SUDS.

There are various methods of estimating silt loads from very simple to complicated.
For most studies it is important to remember that there will rarely be sufficient data to justify the use of more complex methods. Thus for most assessments of silt loading simple

accumulation rates can be obtained from the literature and as a worse case it is assumed it all washes off into the drainage system.

"*The mark of an educated mind is to rest satisfied with the degree of precision which the nature of the subject permits and not seek an exactness where only an approximation of truth is possible.*" – Aristotle

Silt in runoff from construction sites is many times that from normal uses and if this sediment is controlled and dealt with effectively during construction then in subsequent operation the volumes to be dealt with are relatively small. Another major source of silt is poor landscape design and they should be designed to minimise runoff into the SUDS or to treat it effectively.

4. Silt in practise

4.1 Ponds

There are many examples of ponds in other countries that have been in operation for in excess of twelve years without any maintenance and without adverse effects of silt accumulation (Figure 1). A good example is at Hopwood MSA in the UK where limited silt was found in ponds during routine maintenance after eight years. This is because they are part of a management train and most silt is removed before it reaches the ponds.

Figure 1 Pond in USA

In Dunfermline in Scotland the sediment build up in a pond has been monitored over a period of three years (Heal, 2000). The results of the silt build up are summarised in Figure 2.

The change in mean sediment depth indicates that the majority of sediment up to 2001was present at the end of construction. The time to fill the entire pond volume based on the increase in sediment during 2001 is estimated to be 31 years. It is interesting to note that in 2000 very little sediment entered the pond and the elevated level in 2001 may be due to construction activities within the catchment.

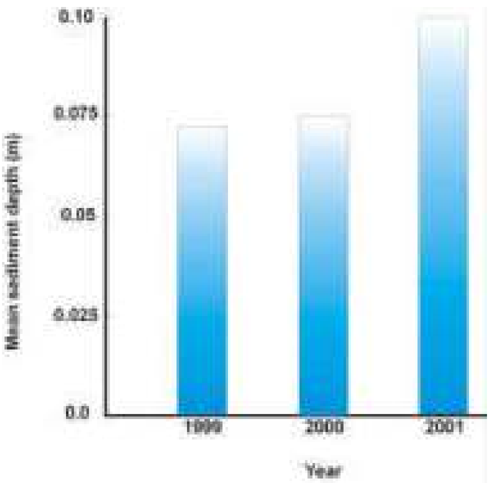


Figure 2 Silt accumulation in pond (Heal , 2000)

Removal of silt is normally required when it fills 25% of the pond volume. In the worst case this will require silt removal after about 8 years. The most optimistic view using the data from 2000 is that silt removal is likely to be required after a much greater length of time.

Theoretical calculations for the catchment confirm this view and it is likely that silt removal may not be required for 95 years.

4.2 Pervious pavements

The infiltration rates of rainfall through pervious surfaces and the long term effects of siltation have been investigated in a number of studies both in the UK and overseas. The results are summarised in CIRIA Report C582 (Pratt et al, 2002) and indicate that in most cases the surface infiltration rate is very high when new (1000's mm/h) but it reduces over time to 100's mm/h. The reduced infiltration rates of most pervious surfaces are so much greater than rainfall intensity that even when left unmaintained the pavements continue to function.

Where clogging has occurred in many instances it appears to be due to runoff carrying soil from adjacent landscaping areas or as a result of clogging during construction. Data also indicates that the clogging eventually reaches a point where further reductions are marginal (Figure 3) and complete blockage and failure is very rare.

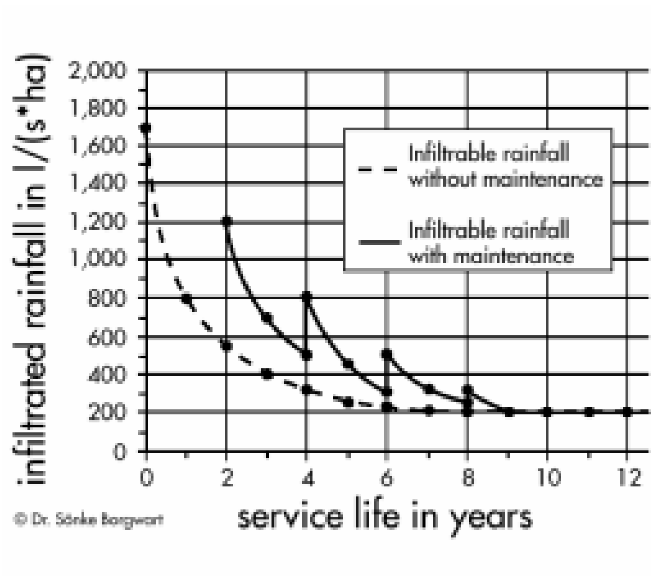


Figure 3 Reduction of surface infiltration (Interpave, 2005)

Much of the evidence indicates that a significant factor in whether a pavement clogs is the presence of adjacent landscaping. American, Japanese, French and German experience with permeable concrete block surfacing suggests that the design infiltration rate should be 10 per cent of the initial rate to allow for clogging over a 20 year life.

Bean et al (2004) tested various permeable concrete block paving with an age range of 6 months to 20 years with various levels of maintenance having being undertaken.

The majority of the concrete permeable block paving had infiltration rates in excess of 350mm/h, despite not being maintained. This is more than enough to deal with UK rainfall.

4.3 Plastic box storage

Computer modelling has demonstrated that silt accumulation occurs in most on line plastic box storage systems. This is good as it is removing pollution from the runoff and is better than letting it flush through the system to damage rivers and streams.

Calculations based on the likely silt loads for a series of worst credible cases have been assessed based on a plastic storage system designed for a 30 year return period for a typical UK site. The results indicate that the loss of 10% of the storage volume will take in excess of 59 years under normal circumstances.

On this basis it would be reasonable to over design the tanks by 10% and allow the silt to build up in the units. Keeping the silt within the tank system has a beneficial effect on water quality and good design to promote siltation in a controlled manner should be promoted. This good design should include designing the tank to promote silt accumulation in areas where it can be removed easily. This does however imply that regular maintenance is important.

The design of these tank systems should move away from large "end of pipe" solutions and the storage should be spread out into smaller tanks around a site. This move towards source control and the use of smaller tanks has three beneficial effects:

1. The risk of excessive siltation from one part of a site affecting the storage for the whole site is removed.

2. The consequences of failure are lower.

3. The cost of reinstatement is reduced if total failure does occur.

Systems whereby silt is simply jetted out are not appropriate to SUDS unless there is some way that the dislodged silt can be collected and prevented from entering rivers and streams.

4.4 Filter strips
Filter strips have been provided at Hopwood Park MSA as part of the SUDS treatment train to a lorry park (Figure 4). The system has been in operation for over 8 years without any routine maintenance of the filter strip. There is no evidence of excessive silt accumulation. If the silt loading on the filter strip is assessed the thickness of silt that would theoretically have accumulated over the eight years is about 0.6mm, ie it will not be noticed in a grassed area.

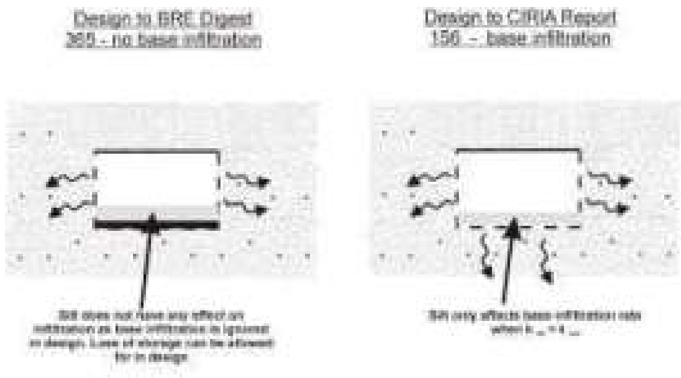
On the basis of both the theory and observed performance the filter strip will last at least 60 year before silt accumulation is likely to be noticed (ie it reaches about 5mm), if at all.

Figure 4 Filter strip

4.5 Infiltration (Soakaways)
Silt will always collect in an infiltration device. There are many thousands of these devices operating satisfactorily in the UK and worldwide. Many engineers think the silt will cause clogging of the device. The risk posed by silt depends on the relative difference between the permeability of the silt and that of the surrounding soil and on the design method used.

If surrounding soil has similar permeability to the silt then there will be little effect. If the design is based on the guidance in BRE Digest 365 then infiltration from the base is ignored and so any silt will have negligible effect (Figure 5).

There are many thousands of soakaways in the UK that have been working for over thirty years with no maintenance. This is probably because in many cases the infiltration capacity of the soil is relatively low when compared to the silt that accumulates and so the reduction in capacity is marginal.



The effects of siltation will be more noticeable when the infiltration rate of the soil is high in relation to that of the silt. Based on typical quoted gradings for silt it will have a permeability of around 10^{-6} m/s and since many soakaways are designed using infiltration rates of around 10^{-5} to 10^{-6} m/s the effects of the silt will be less noticeable.

Figure 5 Soakaway

4.6 Bioretention areas

In some areas of the USA bioretention areas are used extensively in drainage systems. At one site the bioretention area has been operating for over twelve years without maintenance. There is some silt building up at the inlet but the system is still working and based on a visual inspection it is estimated that the system will operate for at least another twelve years before it requires any maintenance.

Figure 6 Bioretention area

The maintenance will simply require excavation of the silt (easily done since the volumes are low) and replacement or regeneration of the filter media.

4.7 High sediment sites

Figure 7 Silt collection in a swale

Some sites will have high sediment loads and the design of the SUDS should ensure that the sediment is collected and then easily removed during routine maintenance. The swale in Figure 7 is working exactly as it should by removing heavy sediment loads from the runoff close to the source and protecting a downstream wetland and the receiving stream. The only problem is lack of maintenance but at least it is obvious that the silt needs removing. On this high sediment site the silt has accumulated within 1 to 2 years.

On high sediment sites such as this surface drainage components where silt accumulation is obvious, and silt can be easily removed, are more effective than underground systems.

A conventional drainage system in a similar site to this has been rendered inoperative by the silt, and rainwater has to be removed by tankers.

5. Conclusions

SUDS systems should be designed to collect silt as this is one of the main methods of treating pollution in runoff. It is unacceptable to allow silt to pass through a system and cause damage to rivers and streams. The SUDS should be designed to deal with the silt so that it does not compromise the operation of the system by causing blockages or reducing storage volumes below the required minimum.

On most sites the silt can be easily accommodated by increasing storage volumes, using source control and adopting the management train principle. For sites with a high silt loading surface SUDS are the preferred option.

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