PERMEABLE PAVEMENTS FOR WATER RECYCLING AND RESUSE: INITIAL RESULTS AND FUTURE PROSPECTS

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SUMMARY

Pervious pavements (meaning permeable pavements within this context and used interchangeably) may be used as storage devices for grey water in order to reduce the demand for mains water. Water collected from roofs may be stored beneath pavements and used for low-grade domestic uses such as landscaping and possibly toilet flushing.

As demand for this water may exceed supply during summer months or in regions with a dry climate, evaporative losses of stored water are significant to the provision of a secure supply. In a series of pilot experiments conducted under controlled conditions, water was stored in a variety of model pavement systems, with and without a geotextile and with different types of geotextile. It was discovered that a geotextile comprising two layers, one permeable but able to attenuate contaminants, and the other providing a barrier to water vapour was significantly better at reducing evaporation than either no geotextile or an oil attenuating geotextile alone.

Where a similar experiment was conducted in a field setting, the two-layered geotextile performed best at preventing evaporation, but the water level was constantly recharged by rainfall, and this allowed water to persist in all of the tested systems. It is hoped to model these results in the context of a theoretical demand for stored water to determine just how much storage may be needed. It is also important to determine the infiltration rates and water quality implications of using the new geotextile.

1. INTRODUCTION

1.1 Water under pressure

Water resources are increasingly under pressure from human activity. With no end to the increase in world population growth forecast and a change in climatic regimes predicted for much of the world, both the supply of clean potable drinking water and the safe disposal of stormwater must be achieved, but these goals represent a 'moving target' as regions in dire need of water become drier (e.g. Sub Saharan Africa) and parts of Europe for example experience flooding linked to higher winter rainfall totals and rises in sea level. If the developed world is to maintain a good standard of living and meet its world development commitments then rational sustainable development programmes must be pursued. The management of urban water in order to prevent flooding comes under the banner of BMP in the US and SUDS (sustainable drainage systems) in the UK. After many years of effort by pioneering engineers, scientists, regulators and policy makers, the message does appear now to be widely acknowledged, that infrastructure must be prepared for heavier winter rain and will require extra water storage, attenuation and treatment devices in order to avoid urban flooding. Despite this,

the other half of the water resources issue, the supply of water and a secure future for this supply is many years behind.

Focusing on the UK, in places the late winter and early spring of 2006 was one of the driest for decades. In the words of the UK Meteorological Office: "In parts of the South-East the previous lowest winter/early spring rainfall totals for successive years (recorded in 1932-34) have been eclipsed. Such deficiencies inevitably imply a substantial degree of drought stress" (Meteorological Office, 2006). At a time when reservoirs should be filling in preparation for summer use, hosepipe bans were in place and groundwater resources for potable use are now under increasing pressure. The Environment Agency (EA) in England reported in May that despite some welcome rainfall, monthly mean river flows had decreased at all sites in Northern England and at half the sites in southern England. Groundwater levels had decreased at two thirds of the EA survey sites compared to the end of April. The majority of sites remain below average and two sites in the Thames Region were still exceptionally low for the time of year (Environment Agency, 2006).

It is clear that water supply in parts of England is a major issue and will increase in magnitude as the climate continues to change. Now would be a prudent time to begin preparing for this future and initiating a coordinated effort to find short, medium and long term solutions as has begun to happen in sustainable drainage.

1.2 Reusing rainwater

There is clearly an increasingly strong case to be made for the re-use of rainwater to take some of the pressure off reservoirs in parts of the UK. Exact figures may be difficult to determine but it is clear that the re-use of stored rainwater, if managed effectively, could supply the water for toilet flushing, garden watering and car washing (Pratt, 1999). This would represent a saving of at least half the mains water used in the summertime when sprinkler systems are used and possibly a third in the winter just from reduced demand for toilet flushing.

The storage element can be fulfilled to some extent by the use of water butts in the garden area but these have a limited volume for storage and look unsightly if they are too large or if there are too many of them. Pervious paving systems (PPS) (meant to mean permeable pavements within this context and used interchangeably) have been shown to contribute to the SUDS/BMP framework for drainage best practice for dealing with both water quantity and water quality problems. The very high infiltration rates into permeable interlocking concrete pavements allow the percolation of rainwater into the sub-base region. The sub-base region represents a large reservoir placed beneath the ground when constructing a PPS sub-base, and it became clear that this area could be used for longer term-storage, rather than just to accommodate the excesses of a heavy storm. In parts of the UK where infiltration is particularly poor or where the PPS is situated on an area with contaminated ground, these systems are bound by an impermeable membrane to prevent water backing up or the exfiltration of contaminated water (see Figure 1), which is the ideal start for the construction of a large underground water storage tank. The advantages of this type of system include:

- A huge volume for storage
- A hidden tank with little or no maintenance
- Possible reduced water bills (UK)
- A tax incentive to increase competitiveness (UK)

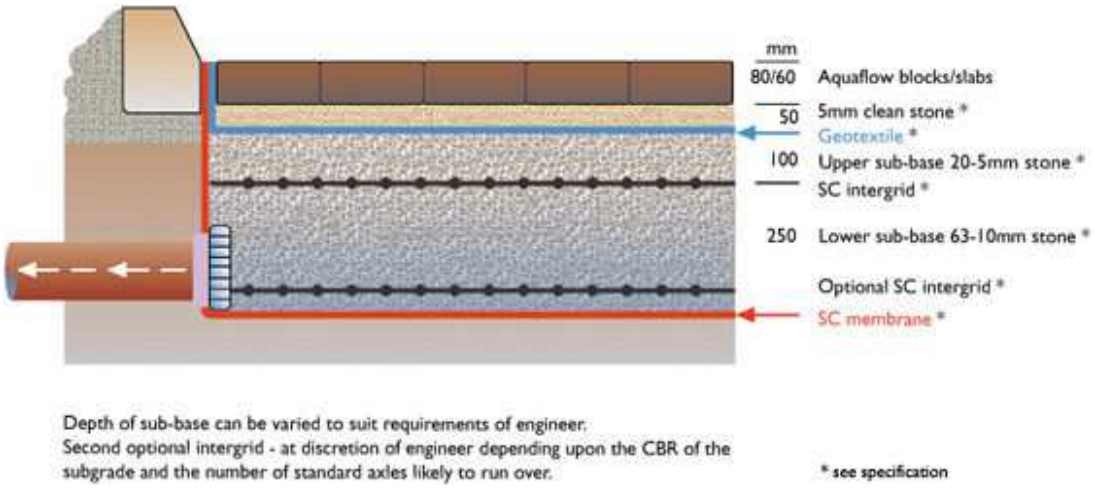


Figure 1. An example of a PPS tanked system.

1.3 A new bespoke geotextile

The case for PPS storage water tanks looks convincing, but if climatic regimes are highly seasonal as they are in many parts of the world, with the current geotextile types available on the market most of the water would evaporate during the dry season when it was needed the most. Clearly there was a need for a new geotextile, one that maintained the pollution mediation properties of random non-woven polypropylene mats with an evaporation control membrane. The result was a new 3 layer geotextile system as shown below in Figure 2.

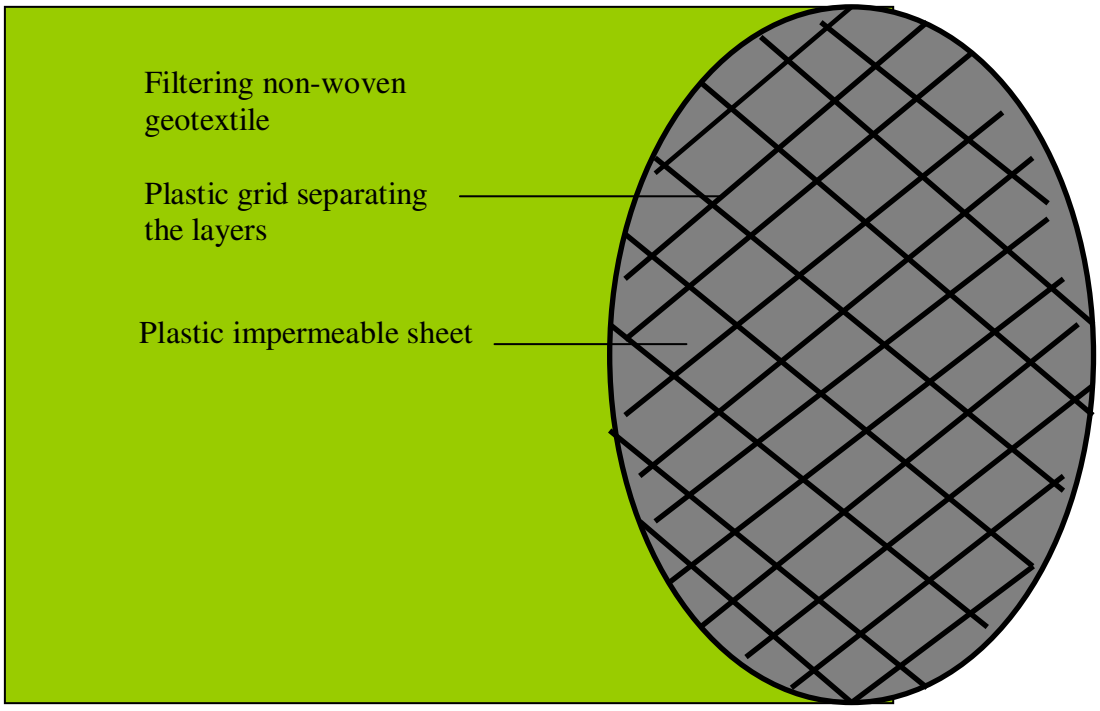
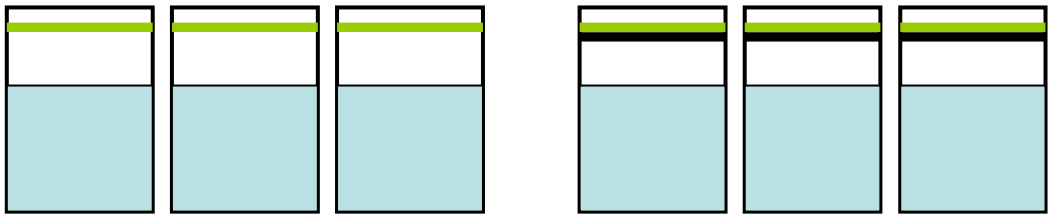


Figure 2. The three layer arrangement of the new evaporation control geotextile.

2. EVAPORATION CONTROL TESTING

In order to determine what levels of evaporation control might be expected from the new geotextile, a number of laboratory trials were initiated along with one field-based trial. Experiment 1 featured 2 litre plastic beakers covered with the ordinary single skin permeable geotextile (PGT) and the new geotextile (NGT) above stored water. This experiment compared the mass lost in water through evaporation over an extended period of time (see Figure 3).



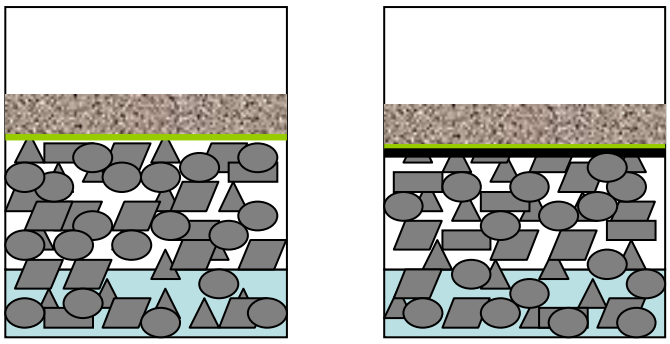
3 beakers with PGT

3 beakers with NGT

1000 g of water added to all beakers

Figure 3. Experiment 1 apparatus and arrangement.

Experiment 2 also featured a laboratory based experiment using beakers. This time less water was used and sub-base materials and the bedding layer were added to make the simulation more realistic.



250 g of water added to 2000 litre beakers 1 beaker containing PGTand 1 containing NGT.

Figure 4. Experiment 2 apparatus and arrangement.

Experiment 3 was based on the roof of the university department and was therefore subject to actual rainfall and evaporation conditions. In experiment 3, due to the difficulty of weighing back the barrels, it was decided to measure evaporation by volumetric determination using the constructed scale on the barrel side. Two barrels had PGT two had NGT and one had no geotextile at all. All barrels had sub-base, bedding layers and pervious blocks included in the construction as well as geotextiles. Before the experiment started the barrels received 3000 ml of water, the level of which was well below the geotextiles.

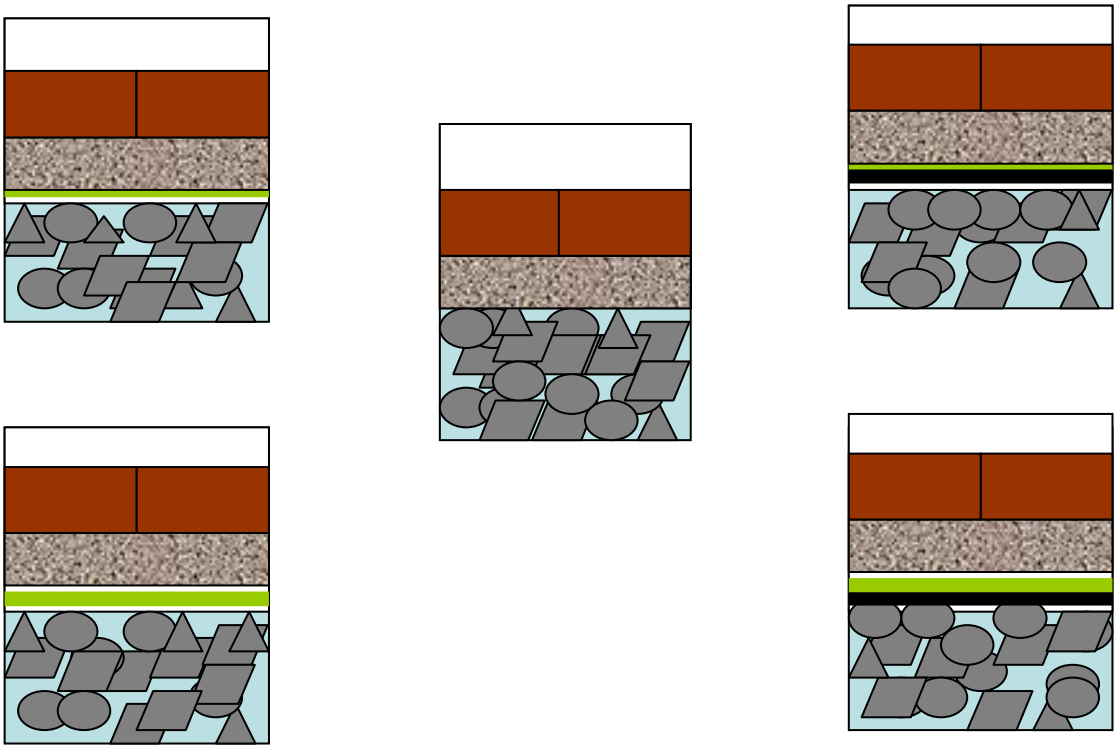


Figure 5. Experiment 3 apparatus and arrangement.

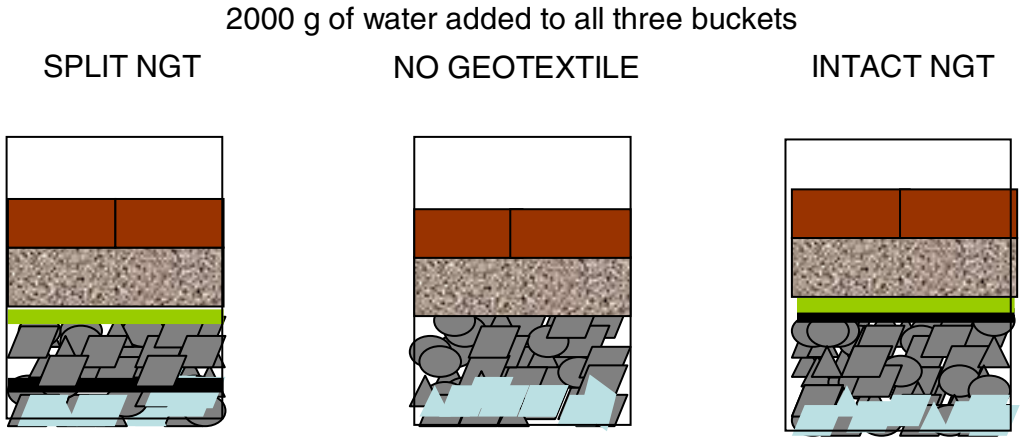


Figure 6. Experiment 4 apparatus and arrangement.

In experiment 4 it became necessary to split the NGT in order to determine the effect of having two discrete layers, the PGT and impermeable layer without the separating grid. Other than this detail the arrangement of the buckets holding the experiment was as in experiment 3 but with 2000 g of water added. It was possible to weigh back the buckets as the trial was laboratory based and received no extra rainfall.

3. RESULTS

The results obtained up to the present date for experiments 1-4 are shown below.

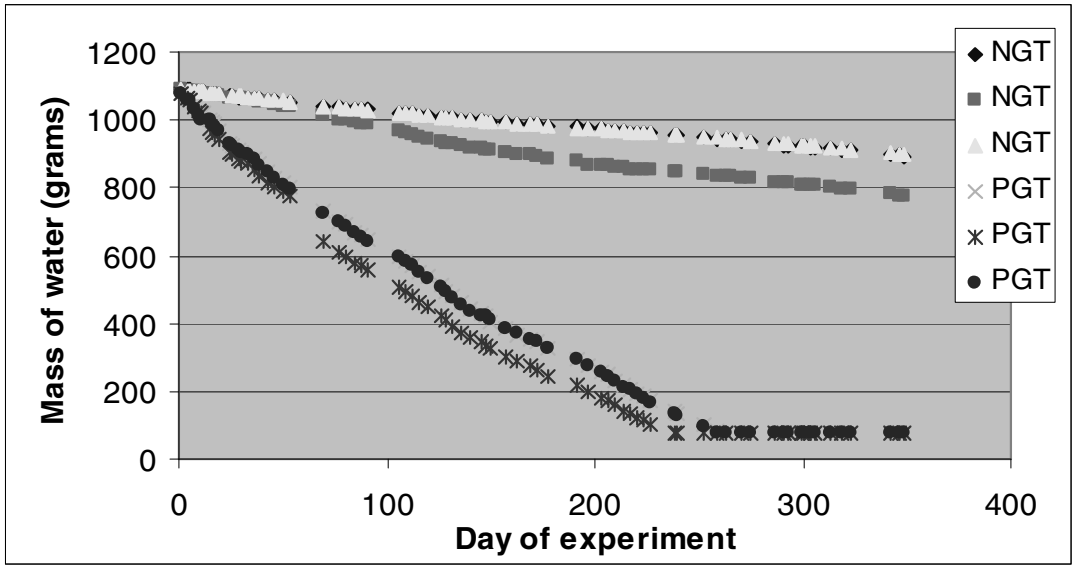


Figure 7. The mass of water lost from beakers covered with PGT and NGT.

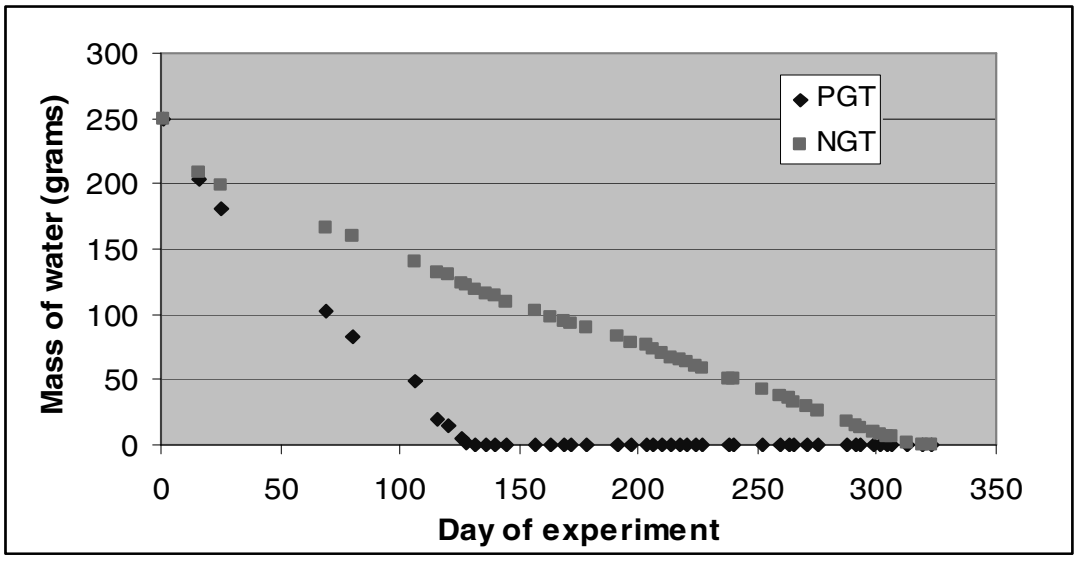


Figure 8. The mass of water lost from beakers covered with PGT and NGT including sub-base and bedding layer.

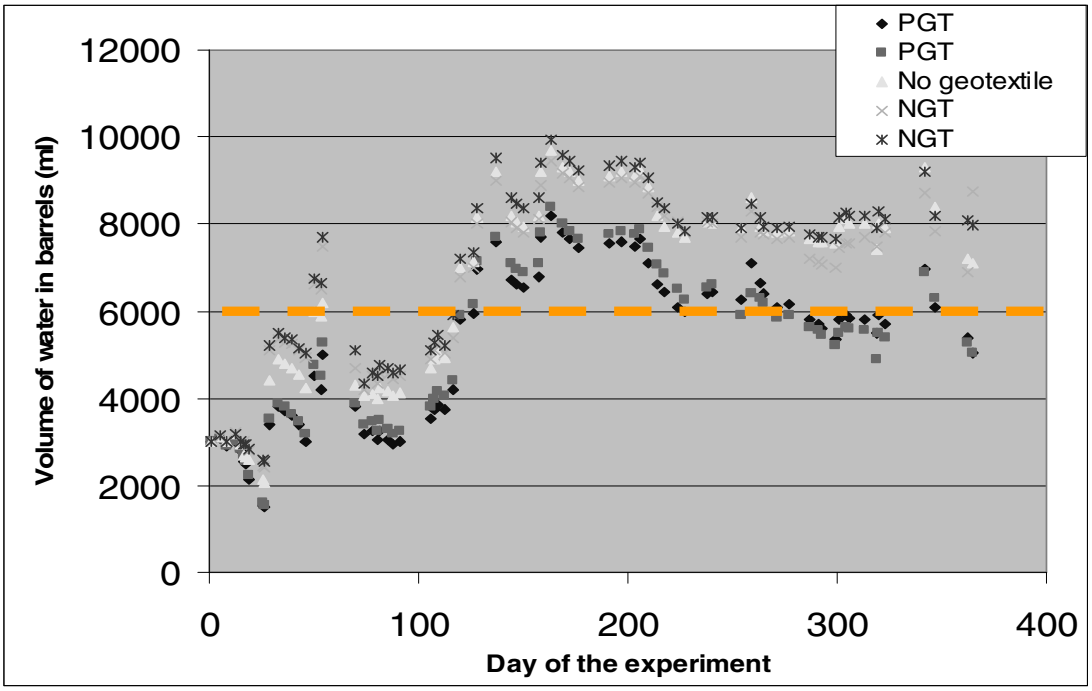


Figure 9. The volume of water in barrels covered with PGT no geotextile and NGT including sub-base, bedding layer and blocks. The dashed line indicates the level of the geotextiles.

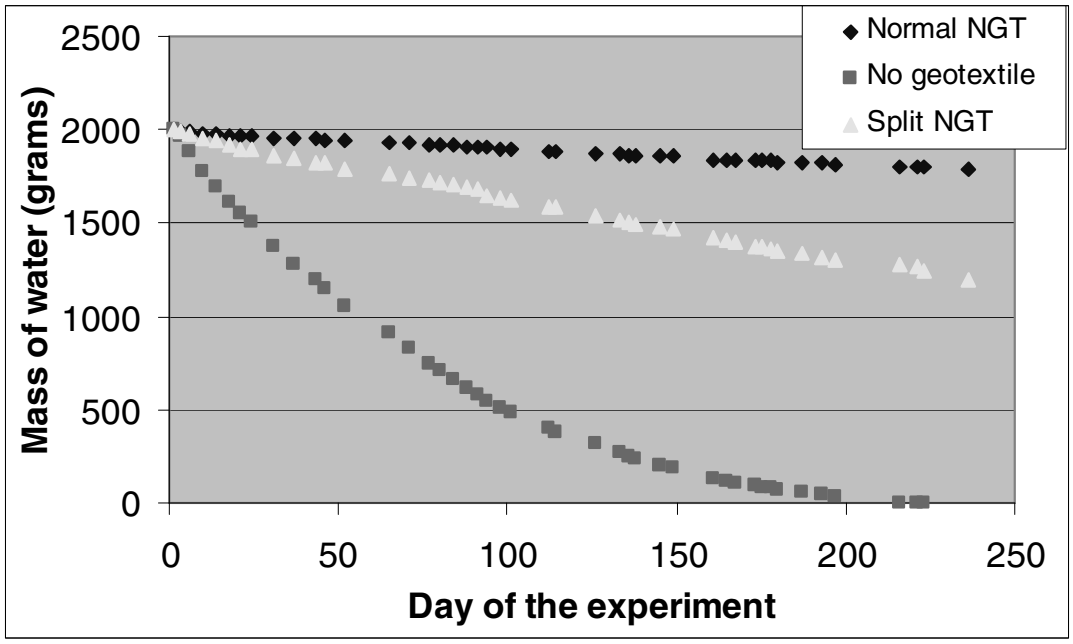


Figure 10. The mass of water lost from buckets covered with PGT no geotextile and NGT including sub-base, bedding layer and blocks.

As can be seen from the graphs above, NGT clearly inhibits the loss of water through evaporation from PPS models. In most of these experiments the loss is quite straightforward as there is no rainfall

recharge of the vessels. With the outdoor barrels however, the fluctuations in volume quite clearly follow the rainfall patterns showing a marked benefit from NGT in the early part of the experiment (days 0-100) and very little increase in difference between PGT and NGT in the wettest winter months. This was primarily because the barrels were effectively flooded, the geotextiles were below water and unable to influence the evaporation rate.

Table 1. Water saving in experiments 1-3 by the use of NGT.

MODEL TYPE (Assessed after 224 days)	*Experiment 1*	*Experiment 2*	*Experiment 3*
Mean mass/ volume H_20 left in PGTmodel	*130.96 g*	*0 g*	*3300 ml*
Mean mass/ volume H_20 left in NGT model	*909.99 g*	*127 g*	*5050 ml*
Mean mass /volume H_20 left in no geotextile model	-	-	*4800 ml*
% water saved by using NGT (relative to PGT)	77	43	31
Water saved by NGT per m^2/day (relative to PGT)	*289.7 g*	*47.78 g*	*103.12 ml*

Table 2. Water saving in experiment 4 by the use of NGT.

Model Type (Assessed after 98 days)	***Experiment 4***
Mean mass/ volume H_20 in Split NGT model	*1638 g*
Mean mass/ volume H_20 left in Intact NGT model	*1894 g*
Mean mass /volume H_20 left in no geotextile model	*514 g*
% water lost by using split NGT compared to intact NGT	*12.8*
Water lost by using split NGT per m^2/ day compared to intact NGT	*34.50 g*

In a country such as the UK with a water surplus for much of the year the benefits of NGT would not be as clear cut. However, with much more seasonal rainfall the benefits would be more obvious. It can

be seen in Figure 10 that a realistic PPS profile, no rain and 3 different geotextile arrangements clearly brings wide variations in the water retention characteristics. Above are summary tables of the NGT versus PGT performance data on water saved in each experiment.

4. DISCUSSION

Experimental data has demonstrated the potential of using NGT in place of PGT for evaporation control. In view of the change to the UK climate and the water shortages in South East England it would appear that a demand for the tanked PPS is stronger than one might expect. Overseas in areas of real water deficit during a dry season, the benefits of NGT and a tanked PPS could be considerable. It is easy to foresee this stored water being used communally as a well would be, or to irrigate gardens and allotments. Even animals may be given their water from this source. The question of how to extract the saved water is a practical issue that needs addressing in order to ensure that a simple, cheap way of accessing the resource. This is important in the developed world to ensure that the cost of tanked PPS installation is not prohibitive and also in the developing world to ensure easy access to water where objects such as electric pumps are not always readily available.

4.1 Infiltration into tanked NGT systems

Infiltration into the tanked PPS with a covering NGT is an issue that is currently being researched by the authors as part of a research degree programme. Of course the infiltration of rainfall through an impermeable membrane could easily become a problem if a most practicable solution cannot be found. The advantage of the traditional PPS with a PGT is that the whole of the surface area is available for infiltration of the water into the sub-base. With the new system it would be detrimental to the water holding function, to have too much of the NGT area pervious to evaporation, but as stated above too little free draining area could lead to siltation and blockage. Clearly this area of work requires some optimisation to ensure an acceptable balance is reached between infiltration and evaporation. Current theoretical and constructed models have identified slitting or slotting as preferable to needle punching or other small-hole solutions.

4.2 Water quality provision

One of the great advantages of using a PPS has been the benefits to water quality in runoff by getting the water below ground and filtering it before discharge. If the upper geotextile was impermeable, the question was raised as to whether a microbial biofilm, responsible for biodegradation of hydrocarbons, would grow as effectively. This was tested by analysing sub-samples of NGT under an electron microscope after subjecting the surface to high concentrations of oil and adding simulated. It had been suggested that rainfall may runoff the impermeable geotextile surface leaving it too dry to support sufficient microbial growth for decontamination.

It was found however that even at the driest parts of the NGT there was considerable microbial growth (see Figure 11 below). It is believed that the PGT layer on top of the impermeable back holds back and traps the water within the space left next to the plastic grid and prevents it from running off.

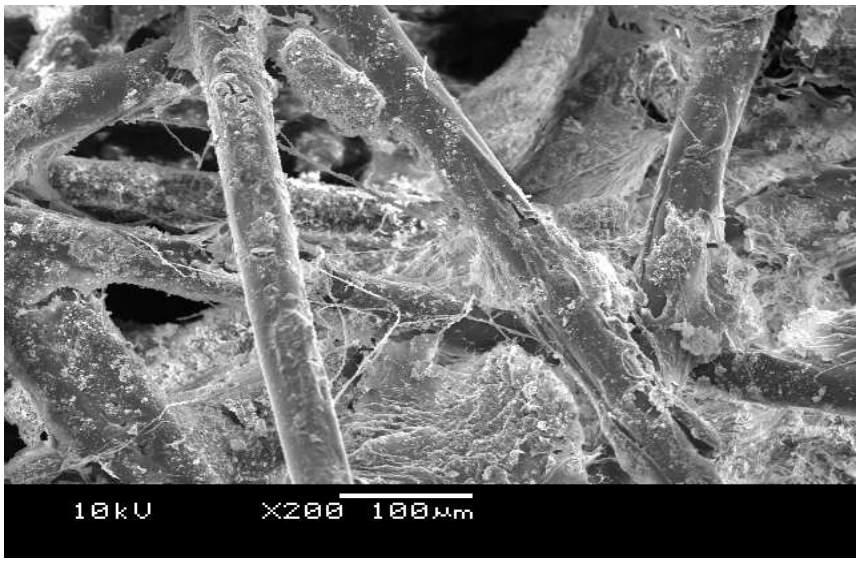


Figure 11. Biofilm growing on NGT after oil contamination.

It may well be that water quality in outflow from a tanked PPS would be higher than from an ordinary PGT system as it would be filtered first by the PGT, would then need to run laterally across the impermeable surface and then be filtered once more before breaking through into the sub-base. As diffuse pollution targets are getting ever more stringent in the UK this will be an area for future optimisation.

5. CONCLUSIONS

It is clear that tanked PPS systems using the new geotextile could play a valuable part in reducing potable water demand. NGT clearly holds back large amounts of water in comparison to the current geotextile in use. As the cost of water increases it will be only a matter of time before these storage systems come into wider use domestically. Water reuse from permeable car parks is already a reality as part of a number of commercial UK SUDS schemes such as community centres, motorway service areas amongst others. These schemes have operated very well to reduce mains demand and to provide a good level of water for customer use. It is within the next few years that on site domestic water storage will begin to take off.

6. REFERENCES

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