EVALUATION OF DIFFERENT CONFIGURATIONS OF STORMWATER TREATMENT CHAMBER

David A. Phipps, PhD, Rafid M. Alkhaddar, PhD, James Dodd
Liverpool John Moores University, UK
(d.a.phipps@livjm.ac.uk; r.m.alkhaddar@livjm.ac.uk; buejdodd@livjm.ac.uk)

Michael G. Faram, PhD, Pamela J. Deahl, P.E.
Hydro International
(mike.faram@hydro-international.co.uk; pdeahl@hil-tech.com)

ABSTRACT

With the objective of reducing the polluting impact of urban run-off on receiving watercourses, various proprietary treatment technologies have evolved, including ‘flow-through’ devices that are designed to intercept and store pollutants such as sediments and floatables for later removal and safe disposal.

Frequently, the performance of chambers is stated in terms of ‘ability to remove pollutants from the inflow’, often at discrete flowrates. However, a parameter that is often overlooked is chamber ‘retention efficiency’, the ability of chambers to retain stored pollutants once collected.

The paper presents the findings of both simulation and experimental studies of different designs of treatment chamber, focussing in particular on the ‘retention efficiency’ parameter. It is concluded that chambers in which the pollutants storage region is isolated from the main treatment area are likely to be most effective.

INTRODUCTION

With increasing urbanization, the problems of stormwater run-off from impermeable surfaces have become increasingly apparent. Run-off often carries a high sediment load, and this, along with other associated pollutants, can have a detrimental impact on receiving watercourses.

Recognizing urban run-off, and in particular, sediments, as one of the main sources of pollution in the USA (US EPA, 1998), Phases I and II of the US stormwater program, initiated by the EPA in 1990 and 2000 under the 1972 Clean Water Act, are leading to significant improvements in the quality of US waters. The regulations largely target non-point source pollution in run-off from urbanized areas where land is often scarce and expensive.

In response to the technical need for compact and effective solutions, various configurations of proprietary ‘flow-through’ treatment device have evolved, designed to intercept and store pollutants such as sediments and floatables for later removal and safe disposal. The most popular of these, which are typically installed immediately downstream of stormwater intake points, utilize hydrodynamic principles to perform their function (US EPA, 1999). These can be categorized as follows;

- ***Gravity Sedimentation Devices*** - Rely on simple gravitational settlement to perform their function.

- ***Simple Vortex Separators*** - Rely on enhanced gravitational settlement to perform their function, through the use of a rotating flow field. Flow rotation results in extended particle residence times, and increased opportunity for settlement to take place.

- ***Advanced Vortex Separators*** - Operate in a similar manner to Simple Vortex Separators, but utilize specially designed internal components to control and enhance performance and provide isolated storage zones for captured pollutants.

Historically, simple catchbasins have been used as entry points to storm drainage systems, their objective being to remove debris from stormwater, preventing clogging in the receiving pipework. However, studies have identified re-suspension and subsequent loss of stored sediments as a potential problem (Lager *et al.*, 1977; Butler & Karunaratne, 1995). In this context, catchbasins can actually represent a source of pollution.

In the current studies, the effect of chamber design on performance is considered, focussing in particular on the ability of chambers to 'retain' stored pollutants.

THE IMPORTANCE OF 'RETENTION EFFICIENCY' AS A PERFORMANCE PARAMETER

The effectiveness of a 'flow-through' treatment chamber can be denoted by two key parameters;

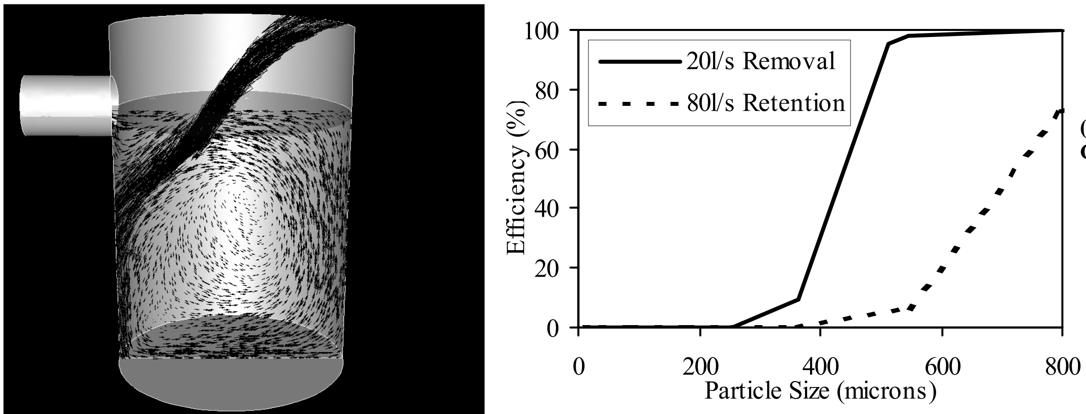
- ***Pollutants Removal Efficiency.*** The ability of a chamber to 'remove' pollutants from the influent. Typically, hydrodynamic separators (including gravity sedimentation and vortex separation devices) attain the highest removal efficiencies at the lower hydraulic loading rates.

- ***Pollutants Retention Efficiency.*** Representing the ability of a chamber to 'retain' pollutants once collected. While related to hydraulic loading rate in most practical cases, retention efficiency is also strongly dependent on chamber configuration.

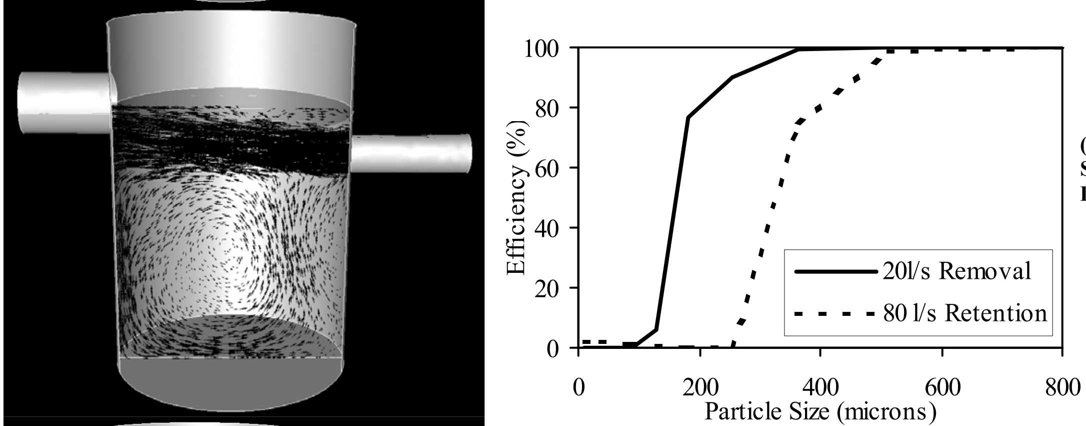
Frequently, the performance of chambers is stated only in terms of pollutants removal efficiency, often at discrete flowrates. Retention efficiency, however, is rarely given consideration. This is thought to stem from the difficulties associated with its measurement, combined with a lack of appreciation of its significance. Difficulties arise due to the fact that retention efficiency is time-dependent, in addition to being dependent upon hydraulic loading rates and stored pollutants characteristics and quantities.

The importance of 'retention efficiency' as a device parameter can be demonstrated through considering the operation of a treatment chamber during a storm event. Hydrodynamic treatment chamber removal efficiencies tend to be at their highest when flowrates are low (i.e. during the early or latter stages of a storm). Conversely, when flowrates are high (i.e. at a storm peak), efficiencies tend to be at their lowest. Assuming that most of the polluting load in a storm flow occurs at the beginning (i.e. in the form of a 'first flush'), it might be deduced that net pollutants removals will be high. However, this is dependent upon the ability of the chamber to retain stored pollutants throughout all stages of the storm profile.

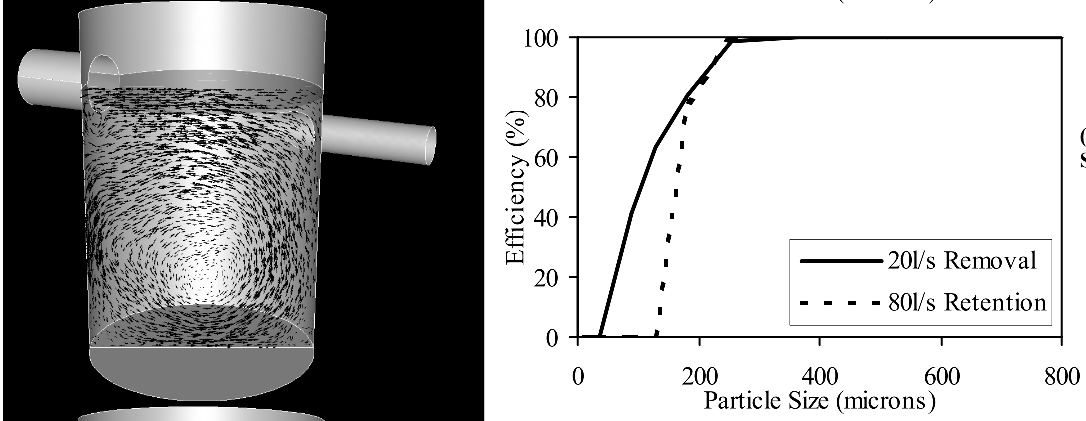
Faram *et al.* (2003) have utilised computational fluid dynamics (CFD) simulation to evaluate different treatment chamber designs, looking at both removal and retention efficiencies. The main findings, presented in Figure 1, confirm the relevance of retention efficiency as a performance parameter, highlighting the importance of sheltering the pollutants storage region in such systems. More recently, experimental research work has commenced to verify these findings, a major component of which is to be conducted at Liverpool John Moores University in the UK, where much expertise in the evaluation of hydrodynamic separation systems is held. This work is described in the following sections.



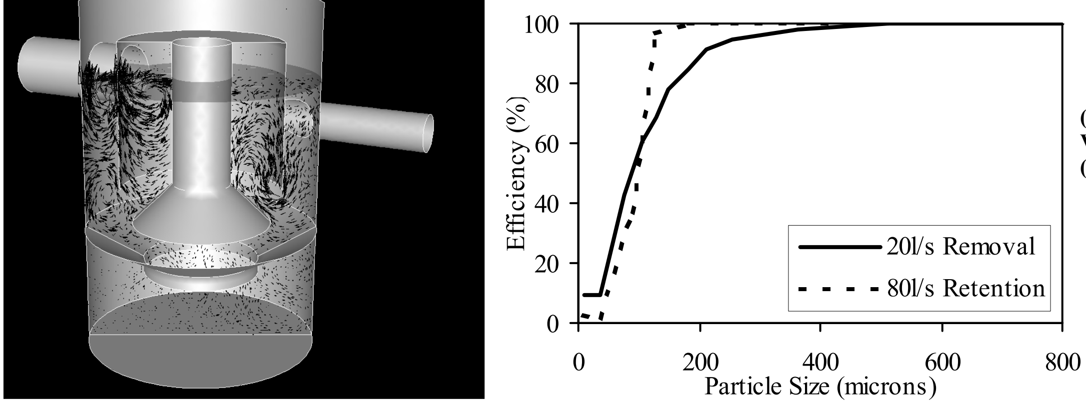
(a) Simple Catchbasin (SCB)



(b) Gravity Sedimentation Device (GSD)



(c) Simple Vortex Separator (SVS)



(d) Advanced Vortex Separator (AVS)

Figure 1 – Flowfield and Particle Removal/Retention Efficiency Predictions from CFD for Gravity Sedimentation and Vortex Separation Chambers (from Faram *et al.*, 2003)

EXPERIMENTAL STUDIES OF STORED POLLUTANTS BEHAVIOUR

A visualisation study has been carried out using the facilities of Hydro International to provide a qualitative comparison of two configurations of treatment chamber. Both of the chambers considered were of the ‘vortex separator’ type.

The first chamber considered (Configuration ‘A’) was similar to the advanced vortex separator (AVS) shown in Figure 1(d), utilising internal components to protect the sediment storage region. The second chamber (Configuration ‘B’) also utilised internal components. However, in this case, the sediment storage region was not fully protected, allowing the vortex core to impinge directly on the sediment bed. Both configurations were selected to be representative of proprietary types of system.

For both systems, fine sand and decomposing leaves were initially allowed to settle in the pollutants storage region on the base. Flow was then introduced at a rate representative of the typical ‘design’ flowrate for this type of system, and the behaviour of deposited material was recorded using a digital video camera. This was enabled by the provision of a rectangular window in the wall of the test chamber, adjacent to the base.

Figure 2 shows frames from the video recording over a 3 second period for Configuration ‘A’, representing the ‘advanced vortex separator’ (AVS) described previously. For this configuration, the pollutants storage region is seen to be quiescent, with little movement of either the sand or leaves. The surface of the settled pollutants can be clearly seen.

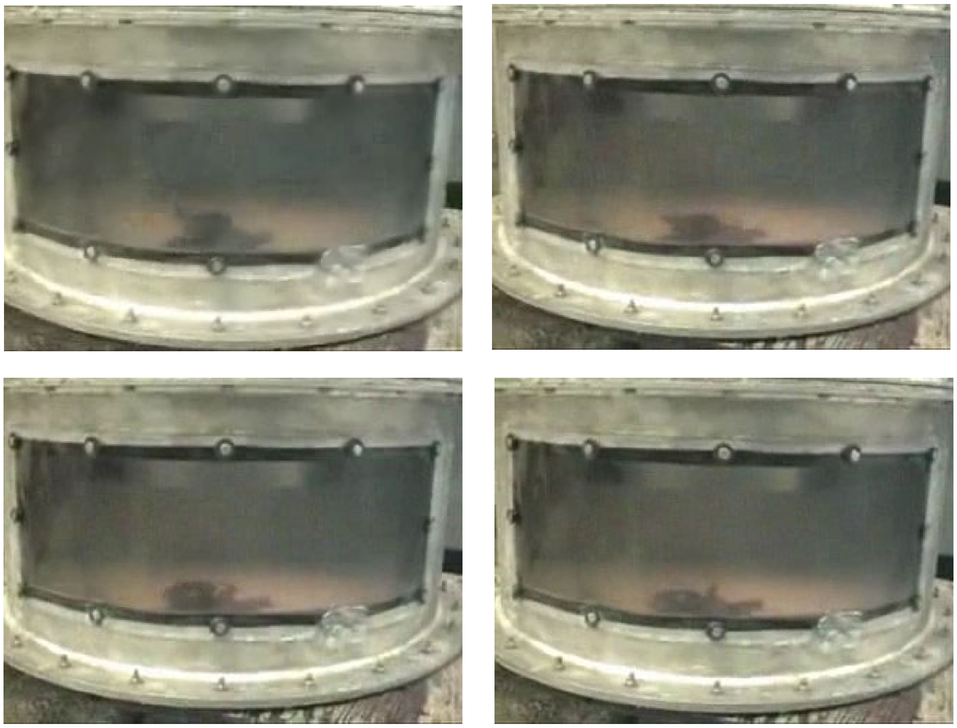


Figure 2 – Behaviour of Stored Pollutants in Configuration ‘A’ – a Vortex Separator with a Sheltered Storage Region – over a 3 Second Period

Figure 3 shows video frames over a 1 second period for Configuration 'B', representing a system with internal components, but poor protection of the pollutants storage region. In this case, a high degree of mixing is observed. While it is difficult to see inside the chamber, due to the high concentrations of suspended sediment, it is possible to see leaves passing adjacent to the inner wall of the window.

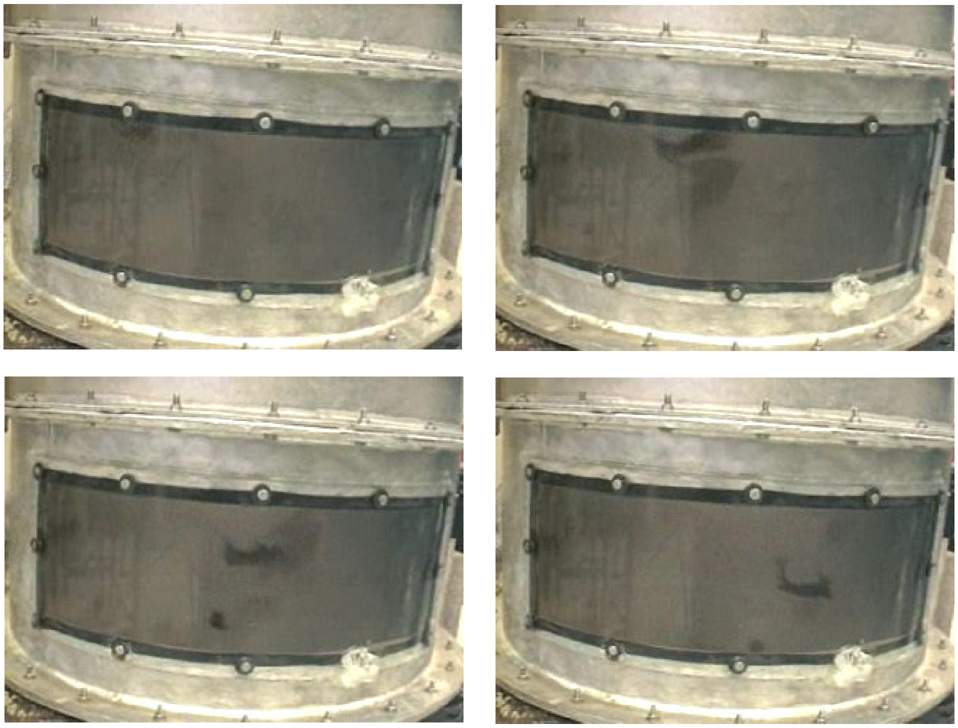


Figure 3 – Behaviour of Stored Pollutants in Configuration 'B' – a Vortex Separator with an Exposed Storage Region – over a 1 Second Period

FURTHER STUDIES USING DYE TRACING

As part of a major programme of studies, a 'flexible' separator chamber has been obtained and installed for testing in the laboratories of Liverpool John Moores University. The test unit provides options to use either a tangential or perpendicular intake, and also to incorporate different internal components. The objective of the studies is to measure the pollutants removal and retention efficiency of different configurations of chamber, and to obtain visual information to support the findings. It is anticipated that this information will provide a useful reference point from which to determine the requirements for 'best practice' design.

As part of an initial study, the chamber was configured as an advanced vortex separator (AVS). Dye was added to the chamber and was allowed to mix and disperse to all points. With the objective of investigating mixing effects in the chamber, clean water was passed into the inlet at a rate substantially higher than the typical 'design' flowrate for this type of system, and photographs were taken at regular intervals.

Figure 4 shows outputs from this study at the time of initiation, and after 1.5 and 3 seconds (note – this is best viewed in colour). Notably, the upper region of the chamber (the treatment region) clears quickly, as the dyed water is washed out of the system. However, the base region (the pollutants storage region) retains dye, indicating flow isolation, thereby confirming its suitability for pollutants storage.

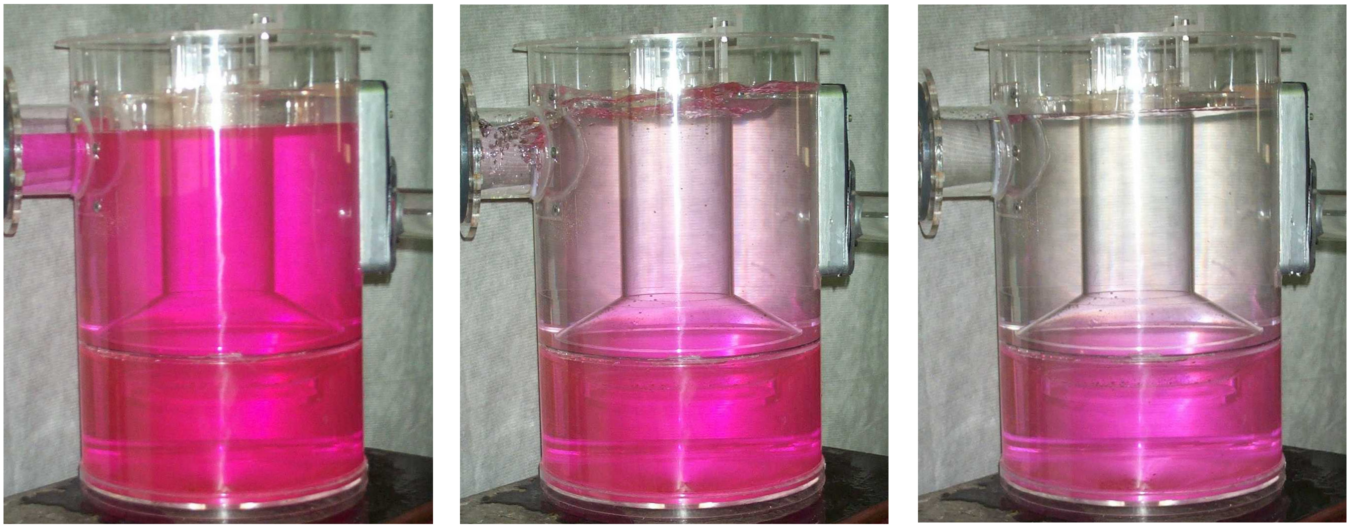


Figure 4 – Dye Tracer Studies Confirming the Ability of the Internal Components in an Advanced Vortex Separator (AVS) to Isolate the Pollutants Storage Region

CONCLUSIONS

The performance of stormwater treatment chambers is generally stated in terms of the ability of a chamber to ‘remove’ pollutants from a contaminated flow. In the current research, the ability of chambers to ‘retain’ stored pollutants is considered. The following conclusions can be drawn from the work;

- Pollutants ‘retention’ efficiency is an important parameter of treatment chamber performance.
- Poorly designed chambers are likely to be prone to wash-out whereby stored pollutants are re-entrained and passed out of the system during high flow conditions.
- A vortex separator system incorporating internal components to shield the pollutants storage region is demonstrated to be superior at the retention of stored pollutants compared to other chamber configurations considered.

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