THE PREDILECTION OF WATER AND GENERIC FILTER AS A MEDIUM FOR URBAN BUILD-UP SAMPLING

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Abstract: Sediment health risk assessment is the principal yardstick of measuring urban pollution. Direct measurement of available sediment in the environment is not common; often an indirect method is employed for the collection of a representative sample at a small scale, which could be scale up to a catchment scale for practical purposes. Therefore, the right choice of a reliable collection equipment and technique that will ensure dependable sample representation is vital in an urban pollution appraisal. The choice of unreliable buildup sampling will have a profound impact on the physicochemical, chemical and bioaccumulation investigations, which could result in flawed conclusion with catastrophic consequences. This study evaluated the weighted advantages of using water as a filter medium on one hand, and the traditional generic filter system on the other for urban dry weather buildup sampling. To ensure objective evaluation, both systems were weighted for bias, comparability, and representativeness. The water-filter recovery efficiency on common particle sizes found in urban roads shows a superior retention efficiency of 99% at particle sizes larger than 2360μm and an overall average of 96%. The major losses were recorded on particle sizes of 1180μm and those lower than 75μm. In all particles sizes range, the entrapment efficiency of the water-filter medium system is higher than regenerative-air sediment collectors, but is comparative with an industrial generic filter system.

Keywords: *Buildup, efficiency, filter, particle size, sediments, suckers, washoff*

1.0 Introduction

Sediments are integral part of our environment and the oceanic biological communities. Sediment acts as a vehicle for carrying and transporting toxins from urban surroundings all the way to estuary and oceans, thereby affecting the aquatic lives. Direct measurement of available pollutants is not common (Pitt *et al*., 2004b), and inappropriate choice of collection techniques could result in an unreasonable model that may give wrong result and conclusions with catastrophic consequences. Therefore, evaluation of sediments collection technique is the yardstick in ensuring veracity of buildup and washoff models. In this study, the efficiency of water and generic filter collection systems were evaluated under field condition and the findings were compared with those reported literature. The objective of this study is therefore to evaluate the weighted advantages of water and generic filter collection systems in buildup sampling.

Research question and objective often determines the best appropriate sampling method to be employed in sediment collection (Zirbser *et al*., 2001). Generally, there are two types of sampling design approaches; the probabilistic and the random sampling. An assessment of national or region contamination favours the former while computing an average value considering the sum total of environmental variables requires the latter. When applying the random sampling protocol, it is important to identify all potential sites and appropriate times of sampling in advance. Irrespective of sampling type and the intended objective, a qualitative sediment study must satisfy three key measurement objectives: sample volume, counts, and duplication.

The most important characteristics of sediments are their natural occurrence in deferring sizes (Zirbser *et al*., 2001); therefore, any successful evaluation of its collection should be able to evacuate the sizes range of interest from the sampling unit with ease and precision. In estuary sedimentology, physicochemical and biological test may require a different amount of sediments for evaluation. Because of the dependency of physicochemical parameters on detection limits and their probable attainment of extraction efficiency by the employed procedure, a precise amount of sediment weight may be required for the analyses; while, for biological evaluation, the weight of the sediment is not considered as important as the test organisms and the test method. The typical volume requirement for estuary sediment has been reported elsewhere (Zirbser *et al*., 2001).

A vast literature exists in the area of estuary sediment collection (Zirbser *et al*., 2001) but there is no standard method for dry buildup collection. Although, there were variant methods used by researchers to collect buildup sediments, ranging from handheld-brushes (Adachi and Tainosho, 2005; Yap *et al*., 2012; Bian and Zhu, 2009; Yuen *et al*., 2012), handheld vacuums (Vaze and Chiew, 2002; Poleto *et al*., 2009), industrial or domestic suckers (Zhao *et al*., 2010; German and Svensson, 2002) to regenerative-air suckers (Pitt *et al*., 2004a). However, because of the ability of the suckers to evacuate sediments on an uneven road's surfaces with ease of operation and efficiency they are the most favoured over the other methods (Egodawatta and Goonetilleke, 2006; Vaze and Chiew, 2002; Zhao *et al*., 2010). In addition, most vacuums nowadays come with dual option of dry or wet samples suctioning (Pitt *et al*., 2004b); this choice would be practically important when comparing results from buildup and washoff samples. In this research, we compared the gainful advantage of using domestic and the industrial suckers for guiding further discussions on the need to draw up a standard. German and Svensson, (2002) compared the efficiency of street sweepers (the Schmidt Cleango suction street sweeper, and the Nilfisk WD 225 F vacuum cleaner) with option of using

High-Efficiency Particulate Air (HEPA) filters and fixed floor nozzles. They noticed that the street sweeper is more effective in removing coarser materials.

Sediment availability, surface dampness, surface roughness, parking condition and equipment operating condition influences the effectiveness of sediment removal from road surfaces (Pitt *et al*., 2004a). The removal performance was attested to lessen with reduction in size of the particles that are known to be prone to re-suspension, these smaller particles are the most promptly washoff from a road throughout downpours and contributes to higher storm water contamination (Pitt *et al*., 2004a); this is in contrast to bigger particles, which are not easily washed-off in runoff (Bannerman *et al*., 1983)

The most important factor hinging on vacuums suckers are the efficiency of the filter system to entrap sediments and their collection efficiency that allows for near total sediments recovery (Herngren *et al*., 2004). Traditionally, industrial and domestic cleaners with HEPA filters are often employed for buildup and washoff collection, but not all are found satisfactorily efficient to pick up accumulated sediments (Bris *et al*., 1999). Recently water filtration technique is being attempted (Herngren *et al*., 2004).

2.0 Materials and Methods

2.1 Materials

The DeLonghi® Aqualand model WFF 1800PET (S1) uses water as a filter medium. It consists of a four litre capacity water reservoir in addition to HEPA filter making it highly efficient entrapper of particulate matter of different sediment's sizes. It comprises of two significant components, the appliance and the supporting tools. The unit design makes it very portable to handle and operate; all components could be assembled and disassembled within a minute. The whole unit measures 7.5kg without suction accessories and 9.0kg when all accessories are integrated. Unlike conventional vacuum suckers, the S1 does not utilise bag thereby allowing it to operate at a maximum suction power of 1.8kW if desired. It can be operated at three preset powers, low, medium and high. It came with two modes of operation, dry and wet sediment collection, which makes it suitable for buildup and washoff collection respectively. The basic characteristic of the two systems are shown in Table 1.

Table 1: Basic features of water and generic filter systems

Filter System	**Brand name**	**Model**	**Capacity (L)**	**Weight (kg)**	**power (kW)**	**Collection mode**
Water medium	DeLonghi® Aqualand	WFF 1800PET	4	9	1.8	dry and wet
Generic filter	SYSTEMA®	BF 585-3	80	31	3.0	dry and wet

The industrial vacuum sucker SYSTEMA® model BF 585-3 (S2) uses a generic filter as a filter medium. It consists of a highly compact 3.0kW motor, 80L capacity storage tank. The filter system housed the motor. The system measures 31.0kg based on manufacturer's specification. Because of its weight and size, S2 requires a trolley to move around and higher voltage input. Like the S1, S2 could be used to collect dry and wet sediments. Further details of this type of suckers can be found elsewhere (Chow, 2011).

2.2 Sampling

Representative samples of the road were collected using a scoop from a road located in front of hydrology laboratory, UTM. The range of particle sizes available on this road were considered diverse enough to cover the range of expected particle sizes on different types of roads. A total weight of 116g of the sample was carefully spread on a selected spot of 1.5x1.0m on a road with a moderate road texture and homogeneity. The road mean texture depth (MTD) was measured using the sand patch method in accordance with ASTM E965 – 96, (2006) method. The MTD was calculated from Eq. 1 as recommended by (Nutz and Hoffmann, 2012; ASTM, 2006).

$$MTD = \frac{4V}{\pi D^2} \tag{1}$$

V is the volume of sample in measuring cylinder (mm^3)
D is the mean diameter of the patch (mm)

Before spreading the sample volume, the demarcated road surface was brushed with handheld iron brush and flushed with a jet of water at high pressure to ensure all permanent storages were dislodged. Thereafter, the area was allowed to dry for four hours under the influence of the sun before vacuuming commenced.

The sampling procedure was similar with the methodology adopted by Egodawatta and Goonetilleke, 2006) and Chow, (2011). For S1, a one litre of water was transferred to its storage tank; the water effectively filters the dust by preventing it to re-suspend into the atmosphere. To enhance the dry particulate matter collection, an adjustable telescopic handle was used on S1 as a tool for convenience and a bristle protrude hard brush was attached at its foot to ensure an in-depth dislodgement of sediments in pronounced joints. The S2 was operated at maximum suction power but without a foot brush. The samples were sucked three times at both directions and one more time along the edges. To obtain the collection efficiency at different sizes for S1, the collected samples were oven dried, and their weights recorded accurate to 0.001g; while a direct measurement of recovered samples was undertaken immediately for S2.

3.0 Results and Discussion

Particle size grading of the original sample is shown in Figure 1, while the recovered weights for both S1 and S2 were compared with the primary sample's as shown in Figure 2. The original weight graph line traced 100% recovery locus. Therefore, the closer the recovered weights of S1 and S2 are to the original weight graph, the minimal the weight loss. S1 indicated better recovery rates. It shows a better recovery potential than S2, especially between 600 and 300µm particle sizes. 1.2, 0.8 and 0.7g constituted the highest loss by S1 in 1180, 4750 and 75µm particle sizes respectively; while the highest weight loss for S2 was 3.8, 1.0 and 0.7g for 600, 300 and 75µm particle sizes correspondingly. From Fig 3, it can be seen that the most pronounced percentile particle losses were in the 75µm size for both suckers, followed by 4750µm and 1180µm for S1 and 600 and 150µm for S2. The major loss recorded in the finest materials (75µm) was expected as most of the particle sizes in this range were mostly particulate matters that can easily be lost between the device compartments and pipe hose. Similarly, Miguntanna, (2009) and Egodawatta, (2007) found maximum loss in this range. Herngren, (2005) recovered an additional 2% of these particles after rewashing the pipe hose. The loss of particles in the range of 1180µm is also common. Chow, (2011) found that this particle range contributed to the majority of efficiency declines in his research. On the other hand, more particles were collected in 6300µm (0.194g) and 2360µm (0. 778g) for S1 than there were in the original sample, this may be due to the brushing action of the foot brush; this type of reading in buildup collection is not unusual (Egodawatta, 2007; Herngren, 2005; Shaheen, 1975). Figure 2 indicated that particle size 2360µm is more prone to additional collection weight, while Figure 3 indicated that 75µm is more susceptible to particle losses.

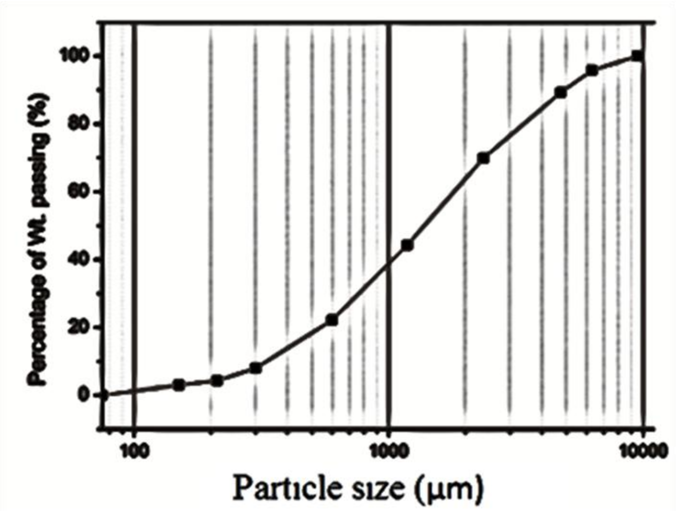

Figure 1: Particle size distribution of the original road sediments

The recovery efficiency between S1 and S2 was compared as shown in Figure3. In all the instances, except 1180 and 4750µm, S1 achieved higher recovery efficiency than S2 despite the fact that S1 was operated at higher suction power. The sheer size of S2, the generic filter used, and the absence of brushing tool may contribute to its lower recorded efficiency. The generic filter used in S2 clearly affected its tendency to retain particulate dregs; this was noticed after vacuuming on the process of dusting-off the filter. The importance of foot brush to dislodge and re-suspend particles from the road texture has underlined its importance in this study.

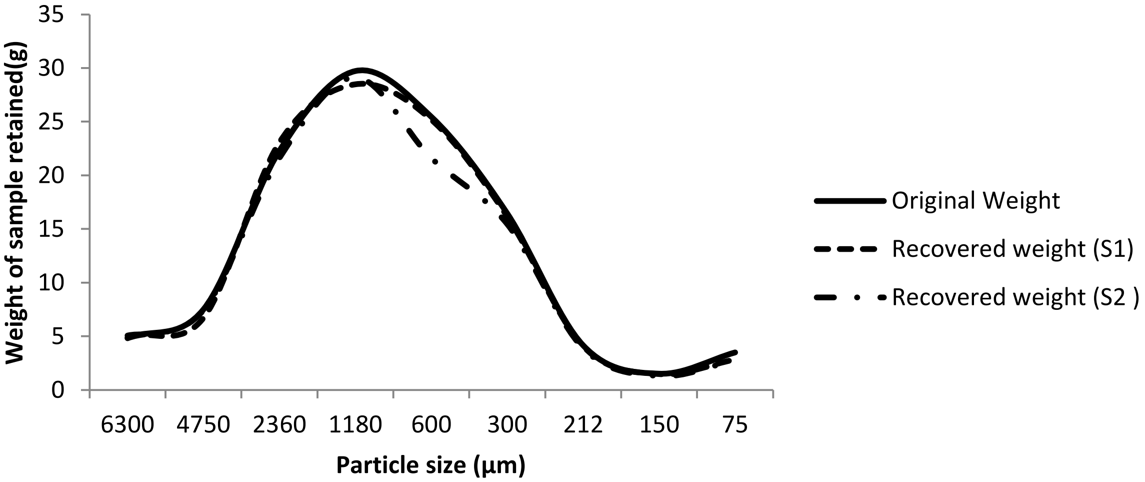

Figure 2: The original weight and recovered weight for S1 and S2.

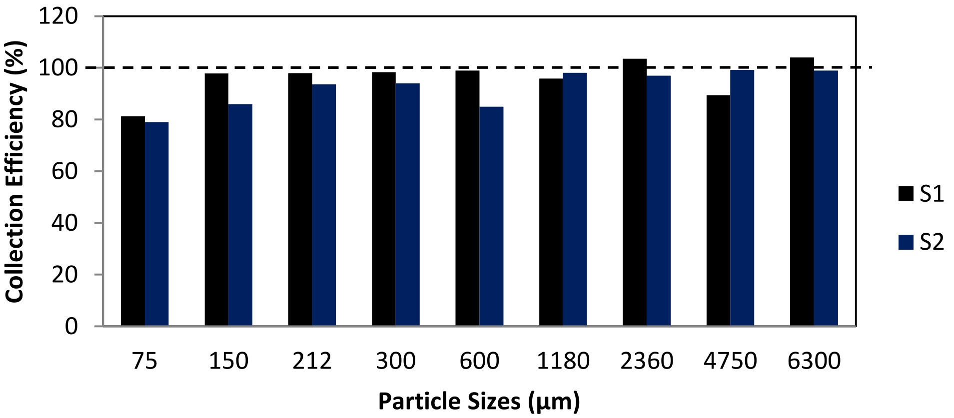

Figure 3: The collection efficiency for S1 and S2

Figure 4 compares the percentile recovery achieved using S1 and S2 from this study and other studies. Figure 4 indicated that the collection efficiency of a regular street cleaner is poor; implying that at any given time, there was attainable road dust that can be available for wash-off. This background residue could certainly vary with the street sweeping method, and the type and efficiency of the equipment employed. The road texture could also play a dominant role in retaining residual pollutants carrying vectors. The highest efficiency achieved using the traditional street sweeper was 79% for particles bigger than 2000µm. The particle suction by the street sweeper indicated that the efficiency declines as the particle sizes become finer. In addition to this trend, the conventional sweeper used by Pitt *et al.*, (2004a) could not suction particle sizes between 40 and 100µm. Generally, from figure 4, the special equipments used for buildup collection shows a similar predisposition to bigger particle collection than finer particles. However, this is not a consistent trend. For instance, Herngren, (2005) found the slightest collection efficiency in particle size range 300-600µm; Miguntanna, (2009) found the least recovered samples at 75-150µm, while this study found the smallest at 75µm for both S1 and S2. From this study, there were two instances of hyped efficiency for S1, at 2360µm and 6300µm. the hyped efficiency at 6300µm could be due to dislodgement of unrestrainedly bound road material by the combined suction power and the brushing action of the equipment, while the hyped in 2360µm could be due to possible addition of aggraded loosely secured materials in water from the particle size of 4700µm. This is evident to the drastic loss of efficiency in particle size 4700µm (89.5%). The overall efficiency of S1 and S2 were 96% and 92% respectively. As shown in figure 4, Pitt *et al.*, (2004a) achieved a mere 45%, Herngren, (2005) and Miguntanna, (2009) achieved 91% and 95% correspondingly. Therefore, sucker with more than 90% efficiency could be considered adequate for collecting unbiased representative buildup samples.

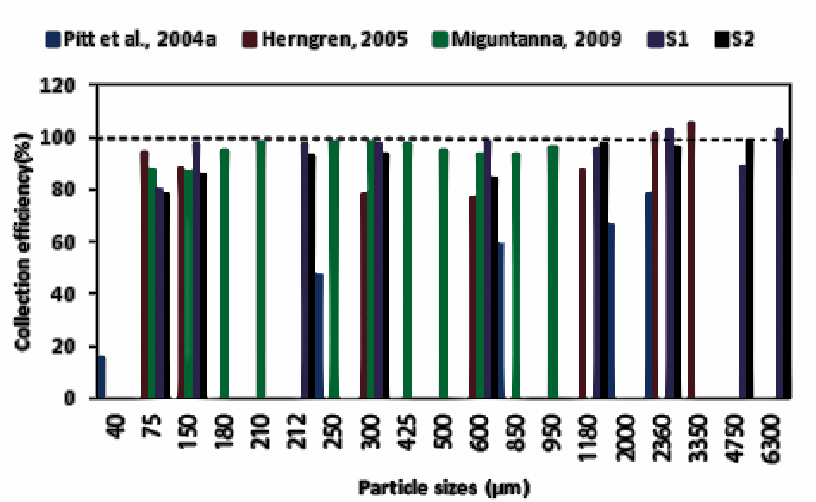

Figure 4: comparison of percentile recovery of this study and other studies

4.0 Conclusions

This study investigated the gainful advantage of using different tools for buildup collection. The lead benefit of using water medium suckers has been weighed against generic filter suckers. Both suckers have advantages and disadvantages, depending upon the research objective. The following summarises the findings from this study:

1. Using water as a medium for filtration in a washoff sample collection may offers an advantage of higher sample retention and minimises the risk of sample cross contamination;
2. The Water filter medium is more efficient in retaining entrapped sediment and would make a sample transfer near perfect. Thus, minimising sample losses due to transfers between containers and ensuring minimal bias between tests;
3. The water filter medium suckers are cheaper to maintain than the generic filters which need replacement of the filter from time to time. Accordingly, the need for periodic filter replacement due to clogging is eliminated;
4. Using a generic filter sucker in buildup sampling could facilitate sample handling and preservation;
5. Since sampling events might be expensive and/or difficult to replicate, it is useful to collect extra samples. This would be helpful in the event of an unforeseen problem during the analytical laboratories, or failure of performance and the need to verify or validate the results. The generic filter system offers this advantage than the water filter medium.
6. The generic filter suckers, due to their sizes, could accommodate larger volume of sediment at any given test.
7. The possibility of recording more particle weights than available weight exists for both generic and water filter suckers once foot brush is used. However, further possibility exists in water filter medium suckers for loosely bound particles to loosen once dissolved in water, thereby transferring the weight to adjacent or subsequent class.

Therefore, the utilization of both sucker would provide an improvement of sample integrity; reduce biases between inter and intra buildup and washoff sampling. The efficiency above ninety percent could be considered adequate for sample representation.

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