A laboratory intercomparison of distributed stormwater treatment devices

Inter-Comparaison de Laboratoire des dispositifs distribués de traitement des eaux pluviales en milieu urbain

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RESUME

L'efficacité des dispositifs de traitements distribués en alternative aux solutions structurelles traditionnelles pour la gestion des eaux pluviales est étudiée en cet article. Le département d'ingénieurs des constructions, de l'environnement et du territoire et le département d'ingenieurs chimiques et de procès de la Faculté de Gênes ont étudié l'efficacité hydraulique de trois dispositifs de traitement différents et la capacité à retenir le chargement polluant de matériels filtrants différents dans le cadre du projets démonstratif ESTRUS (Enhanced and Sustainable Treatment for Urban Stormwater) cofinancé par l'union européenne dans le programme LIFE Environment. Les premiers résultats des tests de laboratoire sont présentés dans cet article.

ABSTRACT

The efficiency of different typologies of catch basin treatment devices as an alternative to traditional structural solutions for storm water runoff management is investigated in this paper. The hydraulic performances of three different treatment devices and the pollutant removal efficiency of different filter media have been studied by the Department of Construction, Environmental and Territorial Engineering and the Department of Chemical and Process Engineering of the University of Genoa in the framework of the Demonstration project ESTRUS (Enhanced and Sustainable TReatment for Urban Storm water) co-financed by the European Union within the LIFE Environment Programme. Preliminary results of the laboratory tests are here presented.

KEYWORDS

BMPs, Catch Basin Treatment Devices, Hydraulic Test, Storm Water, Filter Media Performance Test.

1 INTRODUCTION

In new settlements end-of-pipe solutions for storm water runoff treatment are cost effective and provide high efficiencies since the construction of large size structures for appropriate treatment is included in the overall construction costs and effort. In existing production sites and/or e.g. harbour infrastructures the costs and difficulties of traditional treatment solutions are often unsustainable, the installation of stormwater treatment facilities being therefore postponed indefinitely with strong environmental consequences. Distributed inlet and catch basin filtration devices are proposed as an alternative to traditional systems but they are scarcely used in Europe and few data about their performances in the field are available in the literature. These devices consist of a filter media inserted in a rigid or flexible structure designed for installation directly into the inlets of the drainage network.

ESTRUS (Enhanced and Sustainable TReatment for Urban Storm water) is a demonstration project co-financed by the European Union within the LIFE Environment Programme, which aims at demonstrating the suitability and cost-effectiveness of catch basin treatment solutions for storm water runoff in harbour areas and production sites. Further to the University of Genova the project involves the local authorities (the Municipality, the Province Administration and the Regional Environmental Agency) in charge of authorising storm water discharges and controlling the quality of receiving water bodies as well as the ultimate end-users (e.g. the Port Authority and service providing SMEs).

In particular, the first part of the project aims at evaluating various distributed treatment systems in terms of their hydraulic performances, treatment efficiency and exhausted filter disposal procedure (with a possible energy recovery); this evaluation has been performed by laboratory tests. In the second part of the project the most suitable distributed treatment device will be installed in two production sites and two harbour infrastructures to undergo the field tests.

The present paper deals with the Laboratory Intercomparison performed at the laboratories of DICAT (Dept. of Construction, Environmental and Territorial Engineering) and DICHEP (Dept. of Chemical and Process Engineering) of the University of Genoa. Here different types of catch basin inserts (from geotexile devices to metallic units) have been hydraulically tested with the goal of identifying their critical flow levels and quantifying the volumes of untreated storm water under different flow rates, while filter media have been tested with different physical/chemical tests in order to assess their treatment efficiency.

2 METHODS

2.1 The laboratory framework for hydraulic test

Three different typologies of catch basin inserts have been selected to undergo the hydraulic performance test:

1. *Marathon Materials, Inc. - Catch-All HR I*: characterized by steel frame for overflow and non-woven polypropylene sediment filter integrated with IMBIBER BEADS® IMBICATOR™booms
2. *Ultratech International Inc. - ULTRA-DRAINGUARD*: a fully textile structure with X-tex fibres for hydrocarbons adsorption
3. *Abtech Industries - ULTRA URBAN FILTER*: a rigid plastic device internally filled with Smart Sponge adsorbing polymers.

An “Ad hoc” measurement chain has been designed and set up at the DICAT Laboratory in order to evaluate their hydraulic performances. Such devices are in fact characterized by a common hydraulic overall scheme made of a filtering chamber with an integrated bypass structure. When properly designed, the by-pass activates upon hydraulic failure of the filtering component of the device, so that normal flows enter the inserts while high flows are excluded. The basic requirements of the measuring/testing apparatus can be summarized as follow:

- To provide a constant flow as input over a range of reference flow rates;
- To provide the inlet filters with the same flow regimes they commonly undergo in real catch basins;
- To separately measure the by-passed component and the filtered one;

The system can be subdivided in three main components:

- the input flow (Q_{in}) generating/measuring system
- the catch basin physical model with concentric tanks for flow separation
- the output flow measurement systems ($Q_{Filtered}$ and $Q_{by\text{-}passed}$).

An overview of the different components of the adopted apparatus is presented in figures 1(a) and (b).

The system for the generation/measurement of input flows has been developed in conformity with the UNI EN ISO 5167-2004 standard, “Measurement of the flow rate of fluids by differential pressure devices installed in full circular section lines” and is able to cover flow rates ranging from 0.3 to 4.5 l/s within an extended uncertainty level of 1%.

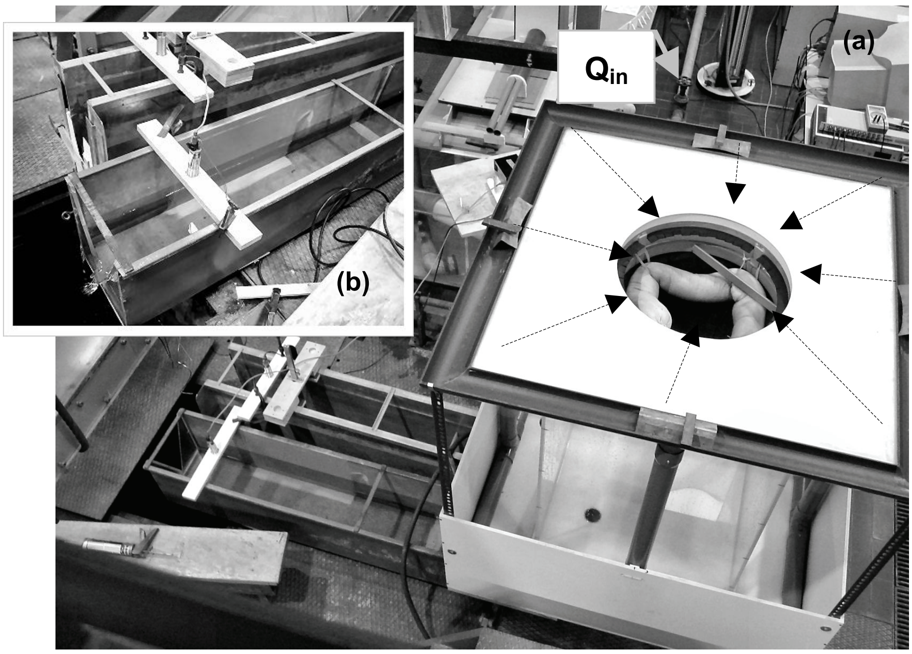

Figure 1 Testing/measurement chain overview (a) and close view of the two rectangular channels equipped with triangular weirs for the measurement of output flows (b)

The measurement apparatus is constituted by a differential pressure transducer installed in a circular section line with 53 mm internal diameter and equipped with a 24.5 mm orifice. The input flow is conveyed to a square gutter spilling into the catch basin inlet. The by-passed and filtered flows are then collected and drained in two rectangular channels respectively equipped with triangular weirs and with high sensitive ultrasonic level sensors (Figure 1(b)).

2.2 Chemical test framework and tools

As regard the chemical physical tests the following engineered filter media have been considered: the *Smart Sponge* filter (AbTech Industries, Inc.) and the *Rubberizer* filter media 8-4 and 4-2 mesh (KriStar Enterprises, Inc.). Both filter media consist of polymeric material chemically selective to hydrocarbons.

First the characterization of the considered polymeric material have been performed. Then the bulk density and the losses of weight respectively at 450°C and 650°C have been estimated.

The bulk density of every sample of material has been estimated by weighing a known volume of sample while the weight losses have been estimated by weighing the material before and after drying it in oven at 450°C and at 650°C for 1 hour.

Concerning the evaluation of the absorption efficiencies of the filter media the laboratory test have been performed in compliance with the Italian Legislation. According to such method, 150 millilitres of motor oil are stratified in a porcelain dish (21 cm i.d.) containing 500 millilitres of water and therefore 10 grams of absorbent product are scattered on the surface. The dish is then placed in thermostat at 25°C swinging horizontally for 5 minutes at the rate of 67 swing/minute.

From the material at the surface two samples have been collected: Sample A consists of 1-2 grams of sample immediately collected and analysed with the aim of estimating the total oils removed by the absorbent material (the absorbed fraction and the oil incorporated between particles), Sample B consists of 2-3 grams of sample analysed after 3 hours of leeching oil in order to estimate the absorbed oil fraction. The analysis of both samples consist of the Soxhlet extraction (extracting mixture constituted by 80 volumes of n-hexane and 20 volumes of methyl-tert-buthyl ether) and of mineral oils determination (IRSA CNR 5140 method).

3 RESULTS AND DISCUSSION

3.1 Hydraulic test results

All the catch basin inserts presented in section 2.1 have been hydraulically tested over a range of input flows Q_{in} from 0.4 to 4 l/s. The series of 13 reference flow rates is reported in Table 1, together with the lower and upper inflow generation limits (±15%). All experiments have been performed in “clean water” conditions in order to assess the hydraulic failures connected with the water conveyance scheme.

Clogging issues are not here discussed and will be approached during the field phase of the LIFE ESTRUS project.

Each experiment consisted of 1 hour test, performed under constant flow and with a stabilization interval between two following tests of at least half an hour. The sampling interval is 0.1 seconds and both the input and output flows are recorded in terms of the average value over a sample of 600 readings (1 minute).

The test results are reported in Figures 2 to 4, where the performances of each catch basin insert are represented in terms of the percentage of discarded flow versus reference flow. The three devices, although with slightly different percentages, seem to better perform at the higher flow rates. This is basically due to the high percentage of water lost due to the dripping out to the by-pass especially for low intensity flow rates.

Lower Limit	*0.34*	*0.43*	*0.51*	*0.68*	*0.77*	*0.85*	*1.06*	*1.28*	*1.49*	*1.70*	*2.13*	*2.55*	*3.40*
Reference flow rate Q_{in}	*0.4*	*0.5*	*0.6*	*0.8*	*0.9*	*1*	*1.25*	*1.5*	*1.75*	*2*	*2.5*	*3*	*4*
Upper Limit	*0.46*	*0.58*	*0.69*	*0.92*	*1.04*	*1.15*	*1.44*	*1.73*	*2.01*	*2.30*	*2.88*	*3.45*	*4.60*

Table 1 The range of testing input flow represented in terms of lower and upper flow limit.

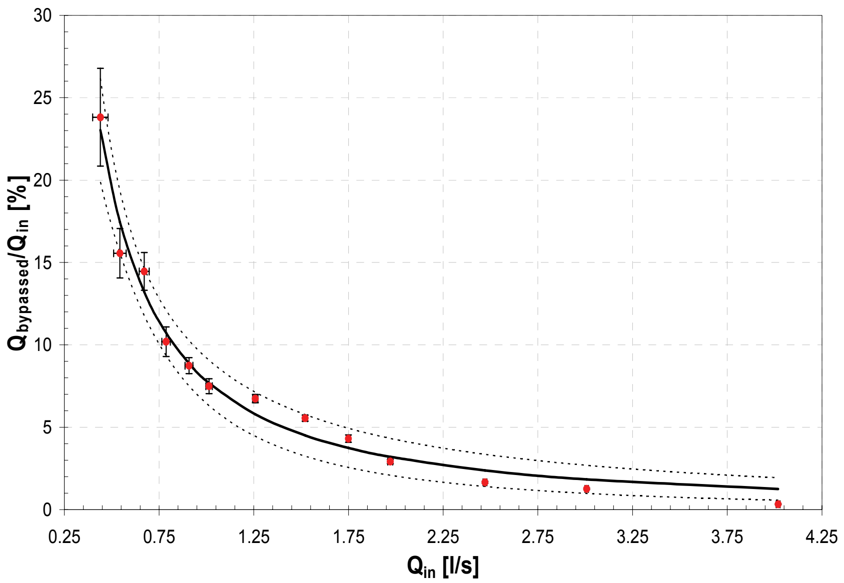

Figure 2 Bypassed flow percentage versus input flow rate for the *Marathon Materials, Inc. - Catch-All HR I* catch basin filter: error bars represent the sample standard deviation for the considered experiment. The continuous solid curve gives the best fit through experimental data, while dashed lines mark off the 99% confidence bounds for the interpolating curve

As an example, in the *Marathon Materials, Inc. - Catch-All HR I*, dripping and spilling phenomena through the bypass are strictly connected with the presence of a rubber deviator internal to the by-pass metallic structure, which is expected to convey water on the adsorbing booms but actually forces low flows to drip through the by-pass.

Such an evidence is particularly relevant since low flows are associated with shorter return periods and also reflect the initial part of rainfall events, usually characterized by the higher pollution load.

3.2 Results from the chemical performance tests

Results of the characterization of the filter media are shown in Table 2. From the results, it is evident that these materials are mainly constituted by organic volatile

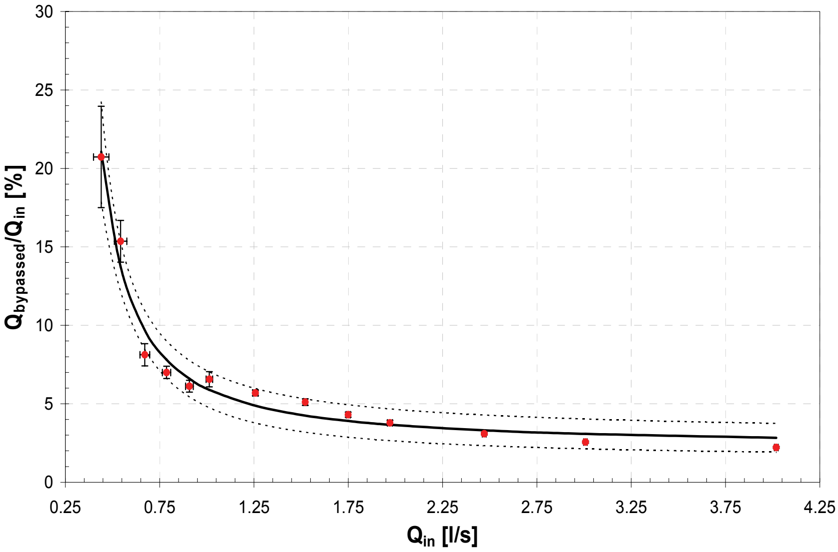

Figure 3 Bypassed flow percentage versus input flow rate for the *Ultratech International Inc. - ULTRA-DRAINGUARD* catch basin filter: error bars represent the sample standard deviation for the considered experiment. The continuous solid curve gives the best fit through experimental data, while dashed lines mark off the 99% confidence bounds for the interpolating curve

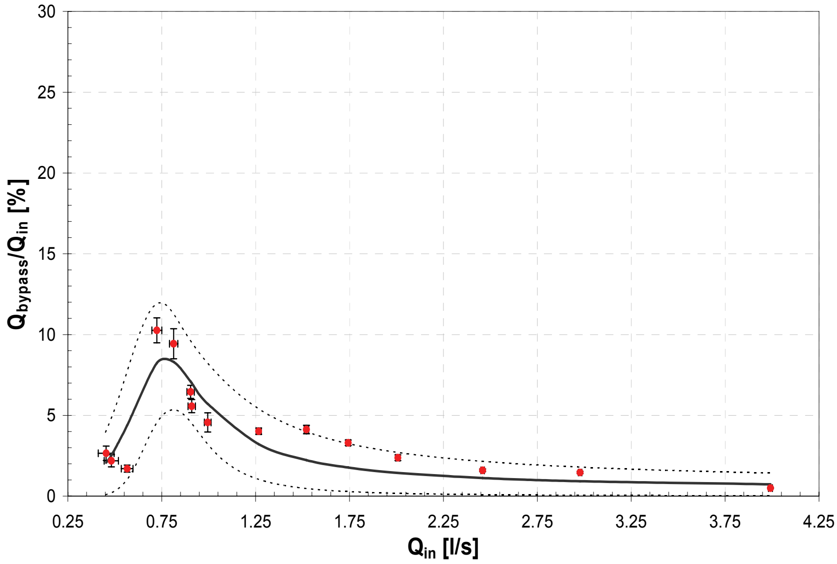

Figure 4 Bypassed flow percentage versus input flow rate for the *Abtech Industries - ULTRA URBAN FILTER* catch basin filter: error bars represent the sample standard deviation for the considered experiment. The continuous solid curve gives the best fit through experimental data, while dashed lines mark off the 99% confidence bounds for the interpolating curve

compounds, because the mineral residue at 650°C is lower than 3% for Smart Sponge media and lower than 0,5% for the Rubberizer one.

	Loss weight at 450 °C [%]	Loss weight at 650 °C [%]	Bulk Density [g/cm^3]
Smart Sponge	91,39	97,48	0,33
Rubberizer 8-4 mesh	99,28	99,61	0,26
Rubberizer 4-2 mesh	99,20	99,60	0,24

Table 2 Characterization of absorbing tested materials.

Table 3 shows the amount of total mineral oils removed (sample A) and absorbed (sample B) by three tested filter media. As it can be noticed the efficiencies of total oils removal vary from 59 to 77%, while the absorption efficiencies vary in the range between 32 and 66%.

Sample		Absorbed mineral oils [mg/g]
Smart Sponge	Sample A	670,06
	Sample B	479,43
Rubberizer 8-4 mesh	Sample A	765,53
	Sample B	663,32
Rubberizer 4-2 mesh	Sample A	585,86
	Sample B	322,98

Table 3. Evaluation of mineral oils absorption by tested materials

4 CONCLUSIONS

The laboratory phase of Life ESTRUS project has been devoted to the performance analysis of different catch basin inlet filters, which will be finally tested against clogging and wearing effects during the field test phase. In particular, both their hydraulic and physical/chemical characteristics have been investigated at the DICAT and DICHEP laboratories of the University of Genova.

Dealing with hydraulic tests, a special apparatus, able to simulate the hydraulic behaviour of a real catch basin has been designed and set up within the laboratory. Such an apparatus, when provided with different constant flow rates is able to separate by-passed and filtered flow components, allowing the assessment of untreated volumes for different types of device.

As regard the hydraulic performance of the three tested devices, in ideal condition in the laboratory (clean water, no clogging) a dripping phenomenon through the by-pass especially for low intensity flow have been observed for all the devices.

As regard the pollutant abatement capacity of the three tested filter media, the preliminary results showed a good efficiency, with a capability of retaining more than half the weight of oils.

5 ACKNOWLEDGEMENTS

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