The ESTRUS project: Performance of catch basin treatment devices in the field

Le projet ESTRUS : performance des dispositifs de traitement distribués sur le terrain

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RÉSUMÉ

Au cours de la période 2006-2008, le Projet ESTRUS (ESTRUS Project - Enhanced and Sustainable TReatment for Urban Storm water) dans le cadre du Programme pour l'environnement LIFE avait pour but de démontrer la viabilité et le bon rapport qualité-prix de dispositifs de traitement des eaux pluviales dans les zones portuaires et les sites de production. Le projet se composait d'une étude préliminaire en laboratoire (non décrite ici), et de la mise en œuvre sur le terrain. Pour cette dernière, une campagne de contrôle a été réalisée sur quatre sites différents à l'intérieur du territoire de la province de Gênes (deux sites portuaires et deux sites de production). Des données qualitatives et quantitatives ont été recueillies à la sortie des systèmes de drainage des eaux pluviales équipés ou non d'un dispositif de traitement, afin d'évaluer leur performance. Cet article rapporte en particulier l'efficacité du traitement concernant les matières en suspension, les hydrocarbures et les métaux lourds, qui représentent les principaux agents polluants associés aux eaux pluviales sur les sites considérés.

ABSTRACT

During the period 2006-2008, the ESTRUS Project (Enhanced and Sustainable TReatment for Urban Storm water) within the LIFE Environment Programme aimed at demonstrating the suitability and cost-effectiveness of catch basin treatment solutions for storm water runoff in harbour areas and production sites. The project consisted of a preliminary laboratory study (not described in this paper), and a following field implementation study. For the latter, a monitoring campaign was carried out at four pilot sites in the territory of the Province of Genoa (two port terminal sites and two production sites). Quali-quantity data were collected at the outlet section of the investigated storm water drainage networks, with and without treatment systems installed directly into the catch basin inlets, in order to assess the field performance of the catch basin treatment devices. This document focuses in particular on the treatment efficiency of suspended solids, hydrocarbons and heavy metals, which represent the main pollutant constituents associated with storm water runoff at the investigated experimental sites.

KEYWORDS

Storm water, treatment, catch basin filter, hydrocarbon, metals

1 INTRODUCTION

During the period 2006-2008, the University of Genoa was involved in a demonstration project named ESTRUS (Enhanced and Sustainable TReatment for Urban Storm water) co-financed by the European Union within the LIFE Environment Programme. The project aimed at demonstrating the efficiency, suitability and cost-effectiveness of catch basin treatment solutions for storm water runoff. As well as the University of Genoa, the project involved the local authorities (the Municipality and Province Administration of Genoa) and the Environmental Protection Agency of the Liguria Region (ARPAL) in charge of authorising storm water discharges and controlling the quality of receiving water bodies. The ultimate end-users were also involved, namely the Port Authority and two service providing SMEs (Finporto S.p.A. and SEPG S.p.A.).

Distributed treatment solutions which remove runoff pollutants directly in the catch-basins or in the initial pipes of the drainage network by means of appropriate devices have been recently proposed as a suitable management and control strategy for mitigating the impact of polluted runoff. These devices consist of a filter media inserted in a rigid or flexible structure designed for installation directly at the inlets of the drainage network. Such distributed devices are an alternative to traditional systems (such as first flush tanks), especially where the latter are unsustainable due to the costs and installation difficulties. Whilst the use of distributed treatment solutions is widespread in the United States, they are scarcely used in Europe and available literature about their performance in the field is only limited (Lau et al., 2001; Morgan et al., 2005; Hipp et al., 2006).

In this framework, the main contribution of the ESTRUS project was to expand our knowledge about the pollutant removal efficiency of the distributed treatment devices in the field and about the most suitable implementation sites, in terms of land-uses, also taking into account the maintenance requirements.

During the first part of the project, the sustainability and efficiency of several catch basin treatment systems were assessed in a series of laboratory tests, looking at (a) their hydraulic performance in ideal conditions (clean water), (b) their treatment efficiency, and (c) their exhausted filter disposal procedure (with a possible energy recovery). During the second part of the project, based on the results of the laboratory phase, the most suitable distributed treatment system was installed into the field in order to evaluate the performance under operating conditions. The monitoring campaign, carried out at four pilot sites within the territory of the Province of Genoa (two production sites and two harbour terminal sites) allowed to acquire a comprehensive database on the quality of storm water runoff discharged through drainage systems equipped or not with the catch basin treatment devices.

The present paper aims at illustrating the results of the field monitoring carried out at the production and terminal sites. This water quali-quantity database will be used to investigate the pollutant removal performance of the selected catch basin treatment device. Particular attention will be given to the treatment efficiency with respect to particulate matter, heavy metals and hydrocarbons, which represent the main pollutants of concern associated with storm water runoff at the experimental sites.

2 METHODOLOGY

As mentioned above, the selection of the distributed treatment device for the field phase was based on the results of a laboratory intercomparison aimed at evaluating the hydraulic performance, treatment efficiency and exhausted filter disposal procedure (with a possible energy recovery) of each investigated device. Note that the hydraulic tests were performed in clean water conditions thus focusing on the hydraulic performance of the devices, whilst chemical-physical tests were performed on the filter media to assess the hydrocarbon removal efficiency. The study revealed that the best results were achieved by the *Ultra Urban Filter®* (Abtech Industries) as documented in previous papers (Berretta et al. 2007; 2008; Molini et al., 2007). This filter was therefore selected for the field phase: a rigid plastic device connected to a metallic conveyance scheme, the distance between the device and the conveyance scheme permits the by-pass of runoff; the system is internally filled with *Smart Sponge®* adsorbing polymers.

2.1 Monitoring sites

Each monitoring station was equipped with an automatic sampler (12 glass bottles with a capacity of 950 ml each) to collect runoff water samples directly from the drainage system. Each sampler was coupled with a tipping-bucket rain gauge and level/velocity gauges for continuous flow measurements. Flow rate data were calculated after application of specific stage-discharge curves: all gauges (rain gauge, level/velocity sensors) had been calibrated at the DICAT laboratory of the University of Genoa before installation in the field. Furthermore, a remote control system, developed within the ESTRUS project for the real time management of each gauge station, was used to retrieve data and vary the sampling conditions in real time. A brief description of the instrumented catchments is reported below.

2.1.1 Oil refinery – Busalla, Genoa (Italy)

The site of interest is the IPLOM S.p.A. (in the territory of the Province of Genoa), whose main activity is the handling and storage of oil products. The monitored area (about 1200 m^2) is an asphalt surface in a good condition, which is situated within the area employed for loading petrol products into the tank trucks. The drainage system is equipped with a first-flush tank (designed to collect the initial 5 mm runoff depth) and a by-pass system that discharges storm water runoff into the receiving water body after filling of the tank. The gauge station will be referred to as ESTRUS 1.

2.1.2 Municipal waste truck depot – Chiavari, Genoa (Italy)

The second experimental site was located within the municipal depot in Chiavari nearby Genoa; the monitored area is employed for parking and maintenance of street sweepers, dumpers and trucks collecting urban solid wastes. The instrumented catchment is an asphalt surface of about 1500 m^2, and the drainage system consists of main pipelines that cross the site area lengthwise with direct discharge into the Entella River. The gauge station will be referred to as ESTRUS 2.

2.1.3 Cruise terminal – Port of Genoa, (Italy)

The third experimental site was installed at the cruise terminal, named “Ponte dei Mille” within the Port of Genoa. The site of concern is used as an access road for trucks and commercial vehicles to supply the cruise liners, and is also employed for parking of private vehicles before embarkation; the monitored area is an impervious concrete surface of about 5000 m^2. The drainage system consists of two main independent pipelines (each sub-catchment area is 2500 m^2) located along the east and west side of the quay, and discharging directly into the sea. Therefore two independent catchments were identified to be used for simultaneous monitoring: in particular a catchment area without treatment system (referred to as ESTRUS 3) and a catchment area equipped with catch basin filters (referred to as ESTRUS 4).

2.1.4 Container terminal – Port of Genoa, (Italy)

The last monitoring site was installed at the VTE (Voltri Terminal Europa) container terminal within the Port of Genoa. The site of concern is an asphalt apron employed for handling and storage of containers, or for the storage of trailers and cars for selling purposes, depending on the varying terminal activities. It has a surface area of about 7000 m^2. The drainage system consists of a main pipeline, located along the side of the apron and discharging storm water runoff directly into the sea, with several secondary pipelines, running perpendicularly to the main collector crossing the apron. Similarly to the cruise terminal, two independent sub-catchments were identified for simultaneous monitoring: the gauge station installed within the sub-catchment without any treatment system is named hereinafter ESTRUS 5, while the gauge station installed within the sub-catchment equipped with the catch basin systems is named hereinafter ESTRUS 6.

2.2 Monitoring campaign

Two different types of monitoring campaigns were carried out depending on the specific characteristics of the pilot sites. For the production sites, the monitoring campaign was organised in two different phases (time-shifted), thus limiting the equipment installation to a single monitoring station for each site: *Phase I* and *Phase II*, respectively, were performed before and after installation of the catch basin treatment devices. This allowed the characterisation of both the raw runoff and the runoff treated by filtration systems directly installed in the catch basins. On the contrary, at the harbour sites and as previously mentioned, the significant surface area of the catchment area and the typology of the drainage systems allowed simultaneous monitoring of two sub-catchment areas, one of which was equipped with the catch basin treatment devices (time-concurrent monitoring campaign). Therefore two monitoring stations were installed for each harbour site.

The monitoring stations provided one-minute runoff flow rate data and discrete runoff samples collected at 5-10 minutes frequency (depending on the sampling activation condition based on flow/rainfall real-time information). One minute rainfall records were also available. As for water chemistry characterisation, laboratory tests of runoff samples were performed by the DICHEP laboratory determining pH, Electrical Conductivity (EC), Total Organic Carbon (TOC), and total hydrocarbons (HC). The ARPAL laboratory examined the samples for Total Suspended Solids (TSS) and heavy metals (copper, zinc, lead, mercury, cadmium and nickel), both as dissolved and particulate fractions.

At the production sites, *Phase I* of the monitoring campaign was carried out from October 2006 to February 2008. During this first field phase 11 rainfall-runoff events were monitored at the gauge station ESTRUS 1 (57 samples overall analysed) and 10 rainfall-runoff events at the gauge station ESTRUS 2 (100 samples overall analysed). During *Phase II* of the monitoring campaign (after installing the catch basin filters), 10 and 14 rainfall-runoff events were monitored at the gauge stations ESTRUS 1 (55 samples overall analysed) and ESTRUS 2 (110 samples overall analysed), respectively.

Regarding the harbour sites, the monitoring campaign was carried out from September 2007 to September 2008. At the cruise terminal, 10 rainfall-runoff events were monitored simultaneously at the gauge stations ESTRUS 3 (drainage system without treatment system) and ESTRUS 4 (drainage system equipped with catch basin treatment devices) with respectively 70 and 65 samples overall analysed. At the container terminal, 8 rainfall-runoff events were monitored simultaneously at the gauge stations ESTRUS 5 (without treatment system) and ESTRUS 6 (with catch basin treatment devices) with respectively 90 and 89 samples overall analysed.

It is important to notice that the monitoring campaign carried out at the harbour sites is particularly relevant for the field phase whose aim is to assess the performance of the distributed treatment systems. Indeed the simultaneous monitoring of two sub-catchments allows the direct comparison of the quality of both treated and untreated runoff in the same hydrologic conditions (rainfall characteristics, antecedent dry weather periods, etc.).

3 RESULTS AND DISCUSSION

In order to illustrate the variability of the pollutant load associated with both untreated and treated storm runoff, water quality data are presented as box plots representing statistical results on a sample basis. The lower and upper boundary of each box indicate respectively the 25^{th} and 75^{th} percentiles, while the thin and thick lines within the box mark the median and mean values respectively. Whiskers above and below each box indicate the 90^{th} and 10^{th} percentiles; individual crosses showed in the plot represent the 5^{th} and 95^{th} percentiles. Figure 1 provides box plots for the concentration of total suspended solids and hydrocarbons, Figure 2 for total zinc, copper and lead thus including both the dissolved and particulate fractions. Note that for each of the examined pollutant constituents the concentration values observed in untreated storm water runoff are represented through the grey filled boxes while the ones observed in drainage systems equipped with catch basin filter devices are represented through the hatched filled boxes.

Table 1 summarises the mean value of the event mean concentration across the whole monitoring campaign and the corresponding standard deviation values with respect to the main investigated parameters for the four experimental sites of concern. The mean EMC values illustrating the quality of runoff discharge without treatment are reported in Table 1(A), while the ones illustrating the quality of treated runoff are reported in Table 1(B). This table will allow a comparison of the ESTRUS database with data available in the literature. However, note that it is difficult to correctly draw any conclusions on the performance of the catch basin treatment device from the sole EMC data. Indeed, the EMC value is a synthetic parameter to measure the pollutant load associated with storm runoff on an event basis. In addition, the mean EMC value is significantly affected by the limited number of monitored rainfall events, as confirmed by the corresponding standard deviation values.

3.1 Total Suspended Solids and Hydrocarbons

The monitoring of untreated storm water runoff (drainage system without treatment devices) allows characterisation of the pollutant load depending on the specific land-use. Figure 1 illustrates that significant concentration values of TSS and HC were generally observed in all sites of concern; in particular both the mean and median values (except for the cruise terminal) were found to exceed the Italian quality standard for discharging directly into the receiving water body equal respectively to 80 mg/l for TSS and 5 mg/l for HC. In addition, EMC values reported in Table 1(A) point out that the TSS load is comparable with data collected from highway surfaces (Legret and Pagotto, 1999 ; Sansalone et al., 2005 ; Kayhanian et al., 2007, etc.) whilst the HC load shows higher EMC values when compared to the ones reported in the literature: for example Kayhanian et al. (2007) observed EMC values of total petroleum hydrocarbons ranging between 0.12 and 13 mg/l, with an average values equal to 2.2 mg/l.

Based on data shown in Figure 1, a different behaviour in terms of pollutant concentration clearly emerges by comparing data recorded at the outlet section of drainage systems with and without the treatment devices directly installed into the catch basins. Note that concentration values are represented in a logarithmic scale.

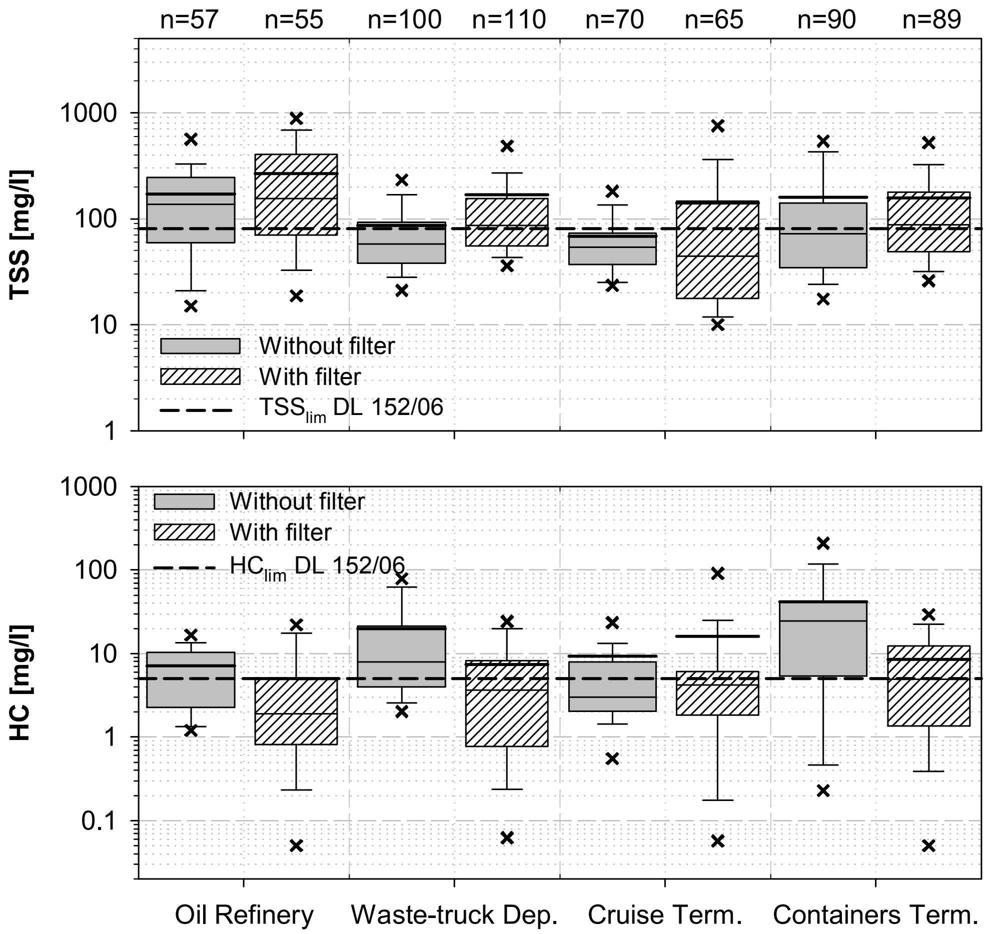

Figure 1. Non parametric distribution of TSS and HC on a sample basis monitored at the 4 experimental sites to characterise storm water runoff without (grey filled boxes) and with (hatched filled boxes) the catch basin treatment systems. The dashed horizontal line indicates the standard limit for discharging into receiving water bodies (according to the Italian Decree by Law 152/06). At the top of the figure the number of analysed samples are reported for each site.

The investigated catch basin treatment device did not reveal any removal efficiency in terms of suspended solids. From data illustrated in Figure 1 (on a sample basis) and in Table 1 (on an event basis), it comes out that the concentration values for total suspended solids were comparable in both treated and untreated runoff. For the harbour sites, the treatment device even seemed to induce an increase in maximum concentration values, and at the cruise terminal site in particular, the treated outflow concentrations varied in a wider range than non-treated concentrations.

The limited treatment efficiency in the case of particulate matter could be ascribed to the specific filter media characteristics: the filter initially detains the solid particles which are washed off afterwards by the hydrograph peak or during the following intense rainfall-runoff event. The analysis of the pollutographs on an event scale seemed to confirm such hypothesis, thus allowing to examine the wash-off delivery behaviour based on the hyetograph and hydrograph characteristics (peak flow rate, antecedent dry weather period, etc.).

On the contrary, the results of the monitoring campaign point out the removal efficiency of the catch basin filter with respect to hydrocarbons in all the investigated harbour and production sites. Although individual samples with concentration values exceeding 5 mg/l were sometimes observed at the outlet section of drainage systems equipped with the catch basin filters, the median values were always lower than the Italian quality standard, as illustrated in Figure 1. For the harbour sites, where the concurrent monitoring campaign was carried out, in the rainfall-runoff events characterised by EMC values exceeding the Italian quality standard (5 mg/l), the absolute percentage difference of the hydrocarbon EMC between treated and untreated runoff ranged from 30 to 94% at the container terminal site, and from 13 to 61% at the cruise terminal site.

(A)

Parameter		***ESTRUS 1 (Phase I)***		***ESTRUS 2 (Phase I)***		***ESTRUS 3***		***ESTRUS 5***	
		mean	*σ*	*mean*	*σ*	*mean*	*σ*	*mean*	*σ*
TSS [mg/l]		183.5	166.9	74.4	36.3	87.5	64.8	197	151
TOC [mg/l]		72.6	88.2	38.7	22.8	16.3	8.3	13.08	3.46
HC [mg/l]		6.6	4.7	9.7	17.2	15.7	34.2	38.6	35.2
Zn [μg/l]	*Dissolved*	78.0	108.8	191.8	110.2	219.8	220.6	346.3	358.5
	Particulate	293.4	166.5	290.3	161.1	125.8	65.4	458.9	334.4
Cu [μg/l]	*Dissolved*	17.1	21.4	50.2	44.8	38.8	41.2	17.2	16.5
	Particulate	54.5	49.3	91.7	65.1	45.4	26.4	47.9	33.6
Pb [μg/l]	*Dissolved*	1.85	1.20	18.6	42.1	1.2	0.4	0.9	0.4
	Particulate	29.8	16.8	38.3	41.4	18.1	9.5	45.5	31.6

(B)

Parameter		***ESTRUS 1 (Phase II)***		***ESTRUS 2 (Phase II)***		***ESTRUS 4***		***ESTRUS 6***	
		mean	*σ*	*mean*	*σ*	*mean*	*σ*	*mean*	*σ*
TSS [mg/l]		291.6	195.0	219.1	316.9	79.8	42.1	229.9	159.7
TOC [mg/l]		25.2	11.5	18.5	7.1	13.3	7.0	17.3	7.8
HC [mg/l]		5.7	7.4	9.9	13.2	13.0	30.1	8.1	6.6
Zn [μg/l]	*Dissolved*	21.6	2.8	85.2	54.6	165.5	123.2	338.8	510.7
	Particulate	294.4	145.8	440.7	630.3	168.5	165.0	592.9	517.3
Cu [μg/l]	*Dissolved*	4.4	2.3	31.9	16.1	34.5	26.9	14.6	14.7
	Particulate	37.7	18.4	186.9	270.4	51.0	35.7	45.1	27.9
Pb [μg/l]	*Dissolved*	1.2	0.6	2.6	2.5	1.13	0.50	1.1	0.4
	Particulate	35.4	18.3	86.0	115.5	19.1	12.1	67.6	49.7

Table 1. Mean EMC values and associated standard deviation of water quality constituents across the whole monitoring campaign with respect to the four experimental sites. Table (A) sums up the pollutant load associated with untreated storm water runoff while Table (B) summarizes data collected in drainage systems equipped with the catch basin filter devices.

3.2 Heavy Metals

As for the heavy metals investigated in the monitoring programme, zinc, copper and lead revealed the most significant concentration values in accordance with experimental results collected during previous monitoring campaigns (Gnecco et al. 2005; 2006). Figure 2 therefore shows the total concentration of those three metals in treated and untreated runoff (i.e. both the aqueous fraction and the TSS particulate-bound fraction are included).

In Figure 2 the Italian quality standards, which only refer to the dissolved fraction, are indicated for each metal together with the quality criteria proposed in 1996 by U.S. EPA (Environmental Protection Agency) in order to assess the impact of discharged pollutants. Note that the US EPA criteria identify both acute and chronic standards for the total concentration of metals, whose values depend on the quality state of the receiving water body. In Figure 2, considering the analysis on a sample basis, the acute concentration values for discharging in sea water are reported for each metal.

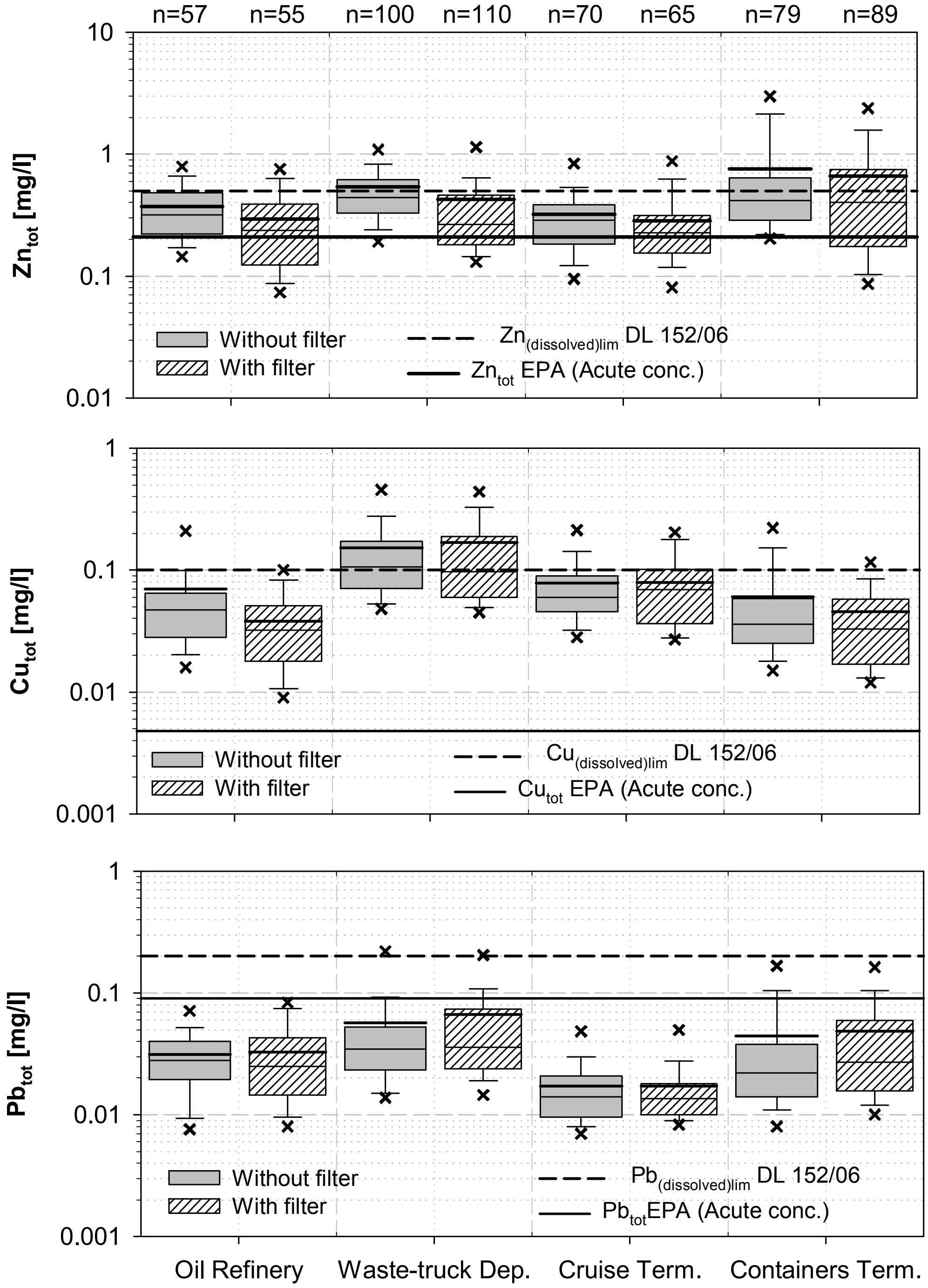

Figure 2. Non parametric distribution of Zinc (Zn), Copper (Cu) and Lead (Pb) on a sample basis monitored at the 4 experimental sites to characterise storm water runoff without (grey filled boxes) and with (hatched filled boxes) the catch basin treatment systems. The concentration values include both the dissolved and particulate fractions. At the top of the figure the number of analysed samples are reported for each site.

From Figure 2 it clearly emerges that the total load of heavy metals associated with storm water runoff was very important irrespective of the fact that catch basins were equipped with the treatment devices. Indeed, the difference between treated and untreated runoff values is almost inexistent and therefore the polymeric filter media does not seem to be effective in heavy metal removal.

By comparing collected data with the corresponding quality standards, it can be observed that copper concentration values exceed the US EPA quality standard while only data recorded at the waste truck depot experimental site exceed the Italian standard, in particular in terms of mean values. Irrespective of the specific land use, zinc shows the most significant concentration values: they are generally one order of magnitude greater than the other observed values, in particular at the container terminal site. Indeed, across the whole monitoring campaign, the mean values of the Event Mean Concentration (EMC) for zinc generally ranged between 0.3 and 0.5 mg/l with maximum concentration values equal to 1 mg/l, whilst at the container terminal site the mean EMC values were equal to 1 mg/l with maximum concentration values equal to 5 mg/l (see Table 1 and Figure 2). Zinc as well as other heavy metals in urban runoff are strongly related to vehicular traffic. Indeed in transportation infrastructures such as roads, highways and parking lots heavy metals follow this sequence in terms of their order of magnitude: Zn>>Pb>Cu as documented in the literature (Barret et al., 1995; Legret and Pagotto, 1999 ; Sansalone et al., 2005 ; Kayhanian et al., 2007, etc.). Therefore, at the container terminal site, the relevance of the zinc load can be ascribed to the heavy and intense activities of trucks on the monitored area.

In order to examine the influence of the filter media in heavy metal partitioning, the behaviour of the dissolved metal fraction index, f_d, calculated as the ratio between the dissolved metal mass and the total metal mass, has been investigated. Figure 3 shows the non parametric distribution of the dissolved mass fraction index, f_d, for zinc, copper and lead; f_d was determined on a sample basis and results are illustrated for both untreated and treated runoff with respect to the four investigated experimental sites. Note that values of f_d greater than 0.5 indicate a dominant dissolved fraction of metals.

Firstly, from data illustrated in Figure 3, the specific behaviour of each heavy metal clearly emerges: zinc and copper reveal their tendency for a predominantly dissolved phase depending on the specific site conditions such as particulate matter concentration and surface typology while lead shows the greatest affinity for the particulate phase, irrespective of the specific land-use and the catchment characteristics. Such behaviour is in accordance with results observed during previous experimental studies (Gnecco et al., 2008) and literature data (Morrison et al., 1990; Dean at al., 2005).

Regarding copper and mainly zinc, the behaviour of the dissolved mass fraction index demonstrates another significant result: both the mean and median values of the f_d index are lower in treated than untreated runoff. In particular, for the terminal container site which is characterised by the most significant concentration of zinc, data collected at the sub-catchment without any treatment device (ESTRUS 5 gauge station) show a predominance of the aqueous fraction as illustrated by the mean value of the dissolved mass fraction equal to 0.52; note that such affinity is limited due to the significant load of particulate matter observed at the container terminal site. On the contrary, at the sub-catchment equipped with the catch basin treatment system (ESTRUS 6 gauge station), the particulate-bound fraction of zinc is strongly predominant as confirmed by the mean value of the dissolved mass fraction equal to 0.34.

Based on the results of the field phase of the ESTRUS project, it emerges that, whilst the filter device directly installed into the catch basin inlet does not remove the total heavy metal load associated with storm water runoff, it affects the partition process promoting the adsorption of aqueous metal on the particles surface: such effect determines a reduction of the dissolved metal fraction which represents the most toxic and bio-available species for the aquatic ecosystem. On the other hand, the investigated device does not show any significant removal efficiency of TSS load, therefore the particulate-bound heavy metals can be transported through the aquatic environment and potentially re-partition to the aqueous phase under specific environmental conditions.

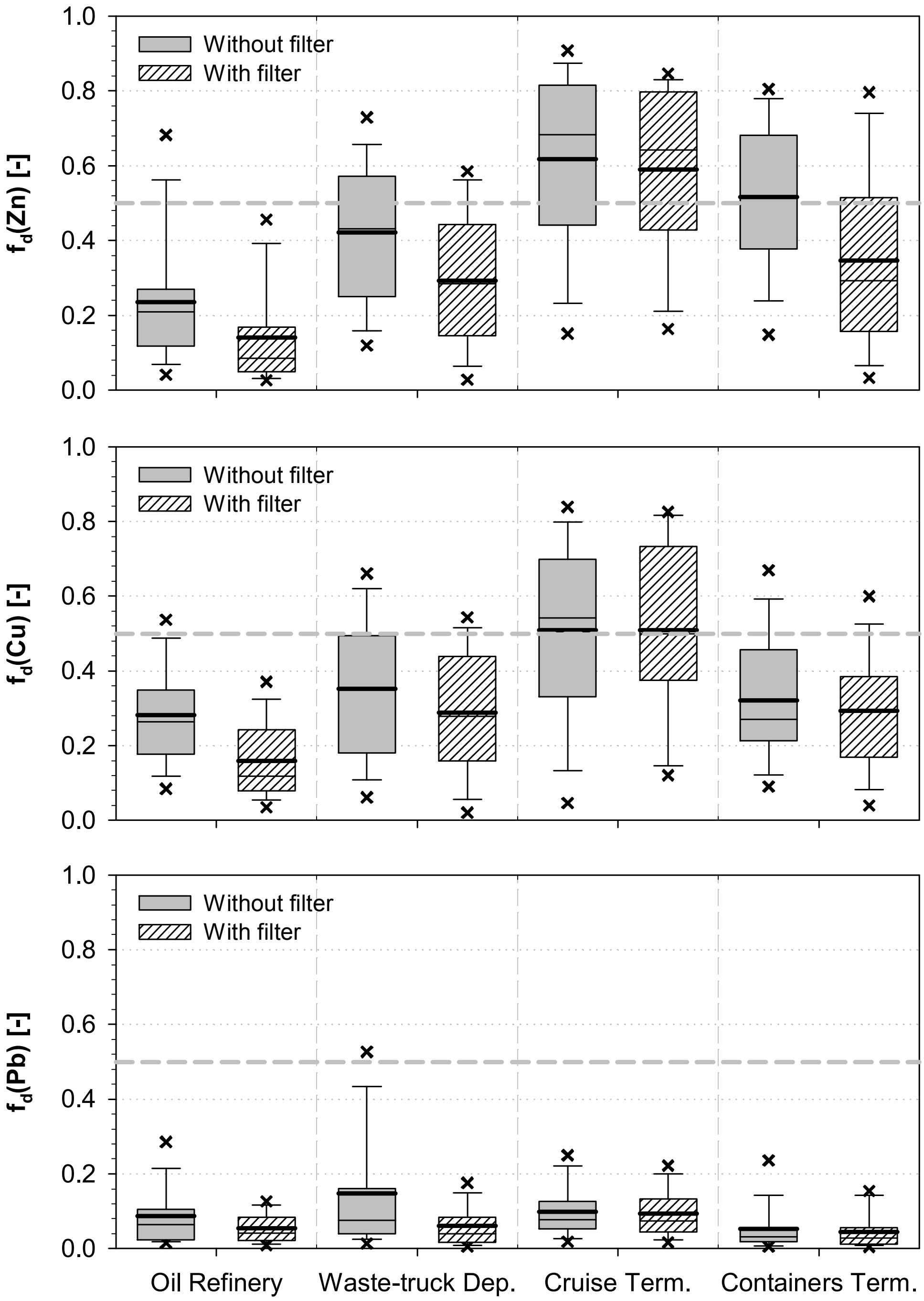

Figure 3 Non parametric distribution of the dissolved mass fraction index, f_d, on a sample basis monitored at the 4 experimental sites to characterise storm water runoff without (grey filled boxes) and with (hatched filled boxes) the catch basin treatment systems.

4 CONCLUSIONS

The ESTRUS project aimed at evaluating the hydraulic performance and treatment efficiency of distributed storm water treatment devices and allowed to point out some crucial aspects both in controlled (the laboratory phase) and operating conditions (the field phase).

During the field phase of the project, the *Ultra Urban Filter*® (Abtech Industries) device has been installed directly into the catch basins of four experimental sites located within the territory of the Province of Genoa (two production sites and two harbour terminal sites). The intense monitoring programme carried out during three years allowed to draw the following main conclusions:

• Water quality data collected at the outlet section of the drainage networks without any treatment system reveal a significant pollutant load at all sites of concern, mainly in terms of suspended solids, hydrocarbons, zinc and copper;

• Removal efficiency of the tested device is relevant in the case of hydrocarbons, in particular the EMC values for hydrocarbons observed in treated runoff revealed a significant percentage reduction ranging between 30 and 94% at the container terminal site and between 13 and 61% at the cruise terminal site;

• The treatment of solids is the critical aspect of the tested device: particulate matter initially trapped into the filter media is washed-off by the hydrograph peak or by the eventual intense rainfall event thus limiting the removal capacity of solids;

• Concerning heavy metals, the overall concentration is not affected by the presence of the filter, although the filtration process promote the partitioning of metals with respect to the particulate bound fraction thus reducing the environmental impact of metal loads on the aquatic ecosystem.

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