QUALITY ASPECTS & BEHAVIOUR OF THE CSO POLLUTANTS IN THE CITY OF SANTIAGO DE COMPOSTELA - NORTH WEST OF SPAIN

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INTRODUCTION

The purpose of this article is to present the results of the fieldwork conducted in the catchment "El Ensanche" located in the city of Santiago de Compostela (Northwest Spain) and to provide a preliminary analysis of the data collected. The aim of this fieldwork is twofold: first, to carry out a hydraulic analysis and examine the contamination discharged by the occurrence of the CSO's sampled, and secondly to calibrate and validate the hydrological and quality models of the catchment under study. This paper will cover the first of the two objectives in a preliminary approach to solving this problem.

OBJECTIVES

Two objectives were pursued:

1. An analysis of how pollution is released during the rainfall episodes sampled (a total of 11), to determine which pollutants are discharged and the possible existence of the phenomenon of the first flush. Also characterised are heavy metals associated with the dissolved and particulate phases.

2. A preliminary correlation analysis between hydrological and pollutant patterns has been carried out.

A BRIEF DESCRIPTION OF THE CATCHMENT "EL ENSANCHE" AND ITS CONTROL SECTION.

The catchment studied here has a combined urban sewer network serving a population of approximately thirty thousand. The surface area covers around 45 hectares having an imperviousness of 94.5%. This is a commercial and residential area, exhibiting the characteristics typical of an urban zone with a high population density and heavy traffic flow. A total of 68% of the area has been developed and the remainder consists of streets and parking areas.

One of its most important characteristics is the steep slope of the streets, averaging 4.2%, with a maximum slope of 13.3%. This fact is highly relevant to the hydrological and the pollutant behaviour. Catchment concentration time is approximately 30-35 minutes.

The figures below show the catchment studied within the city's general drainage system (figure no 1) and a view of this catchment with its sewer network and control section (figure no 2), which will be described later.

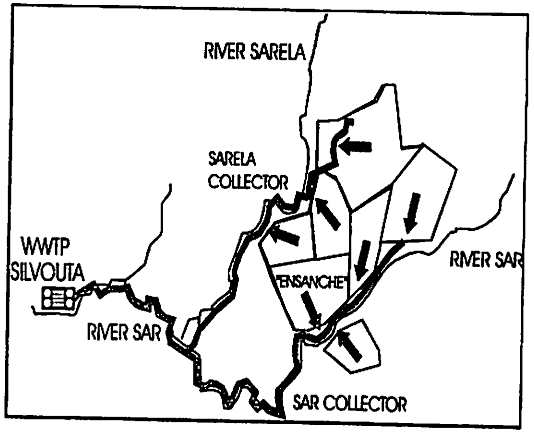


Figure 1: Drainage system of the city of Santiago de Compostela.

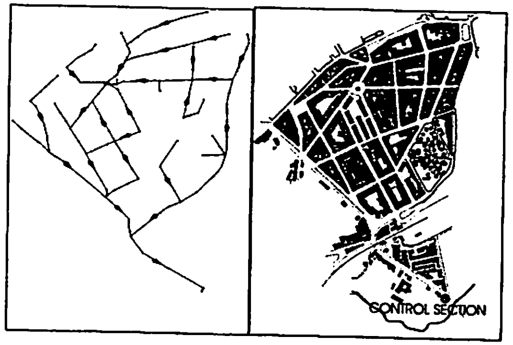


Figura 2: View of the catchment with its sewer network and control section

At the low point of the catchment a control section was set up where, to date, a total of 11 rainfall events have been sampled, collecting information on total flows and pollutant parameters, including solids, heavy metals and organic carbon among others. A rainfall meter was installed at the catchment to provide reliable data on rainfall.

METHODOLOGY

The methodology used consisted of the following stages:

1. Fieldwork to collect flow data and to sample each event analysed.
2. Lab tests to obtain pollutographs from each pollutant.
3. Deskwork using statistical techniques to analyse and process previously obtained data. Preliminary conclusions in terms of the hydrological and pollutant behaviour of the catchment.

We will not go into depth on the first two sections but we will focus thoroughly on the third. Based on all of the information gathered from 1 and 2, we were able to draw up a number of parameters, which are summarised below and which provided the basis for the subsequent statistical analysis:

Pluviometric parameters:

DTSP: duration of previous dry weather (days).
P: total precipitation height (mm).
D: total duration of the storm event (hours).
Imax: maximum rainfall intensity (mm/h).
Imed: mean rainfall intensity (mm/h) or *P/D*.

Hydrological parameters:

Qmax: maximum flow (m^3/s).
Qmed: mean flow (m^3/s).
Vw: total volume per surface unit (l/m^2).

Pollutant Parameters:

Mss: total mass of SS mobilized per surface unit (g/m^2).
Qss_{med}: mean mass flux of SS (mg/s).
Qss_{max}: maximum mass flux of SS (mg/s).
CMSss: event mean concentration of SS (mg/l), or *Mss/Vw*.
CMS_{DS}: event mean concentration of DS (mg/l).
SSmax: maximum concentration of SS (mg/l).
CMS_{ZN}: event mean concentration of Zn (mg/l).
CMS_{CU}: event mean concentration of Cu (mg/l).
CMS_{Pb}: event mean concentration of Pb (mg/l).
CMS_{TOC}: event mean concentration of TOC (mg/l).
Cmed: mean conductivity (µS/cm).
Cmax: maximum conductivity (µS/cm).

GENERAL DESCRIPTION OF THE EVENTS SAMPLED

The following table (table no. 1) presents a summary of the minimum, mean and maximum values and the standard deviation of the different parameters mentioned in the above section pertaining to the 11 events analysed:

Table no. 1: A summary table of the values of the parameters analysed in the 11 events examined in the catchment "El Ensanche", Santiago de Compostela (Spain)

Parameter	Values			
	MIN	MEAN	MAX	Standard Deviation S
DTSP (days)	0.16	7.3	30	9.1 (11)
P (mm)	1.09	3.1	7.3	1.7 (11)
I_{max} (mm/h)	2.6	5.5	7.5	1.7 (11)
I_{med} (mm/h)	0.96	2.1	5	1.2 (11)
D (h)	0.33	1.8	5	1.2 (11)
V_w (l/m^2)	1.44	8.2	19.5	5.6 (11)
Q_{max} (m^3/s)	0.38	0.9	1.6	0.4 (11)
Q_{med} (m^3/s)	0.25	0.5	1.07	0.2 (11)
M_{ss} (g/m^2)	0.74	2.8	4.58	1.5 (11)
SS_{max} (mg/l)	394	848	1472	332 (11)
Qss_{max} (g/s)	282	581	1148	251 (11)
Qss_{med} (g/s)	102	227	528	133 (11)
CMSss (mg/l)	183	415	711	173 (11)
CMS_{DS} (mg/l)	148	446	1025	336 (6)
CMS_{Cu} (µg/l)	102	203	353	92 (7)
CMS_{Zn} (µg/l)	206	366	567	120 (8)
CMS_{Pb} (µg/l)	51	133	241	73 (8)
CMS_{TOC} (mg/l)	6	38	66	22 (7)
C_{max} (µS/cm)	180	1359	3350	1278 (8)
C_{med} (µS/cm)	156	1153	3010	1141 (8)

( ): no. of values.
Table no. 1

Table no. 2 shows the event mean concentrations for the heavy metals Cu, Zn and Pb from the *National Urban Runoff Program* (EPA, 1983):

Parámeter	CMS (µg/l)
Cu	43
Zn	202
Pb	182

Table no. 2 (ASCE, 1992).

Shown next are two of the eleven events analysed (events 17/10/98 and 16/9/99) with their respective graphs (figs.nº 3-12) in addition to two standardised graphs with the 11 events that give an idea of the phenomenon of the first flush in the catchment (figs.nº 13-14).

Event 17/10/98

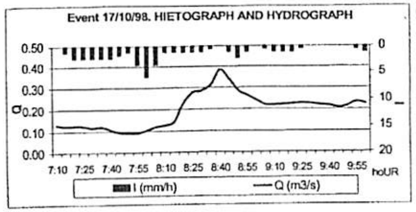
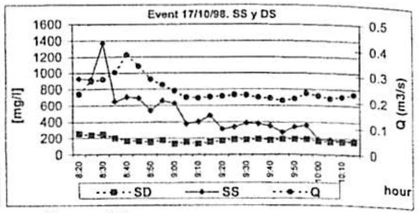


Figure nº 3



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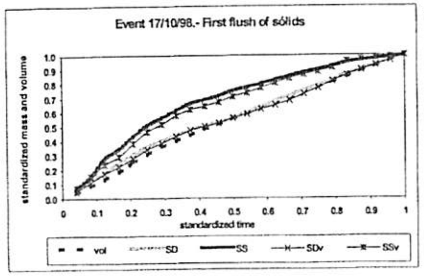

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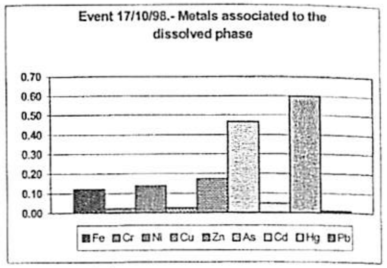
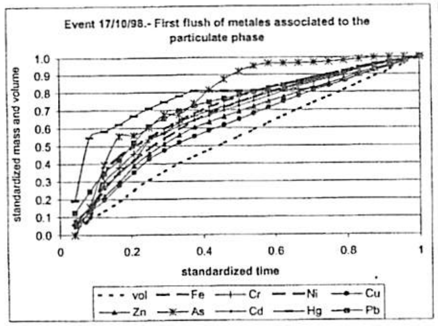


Figure nº 6



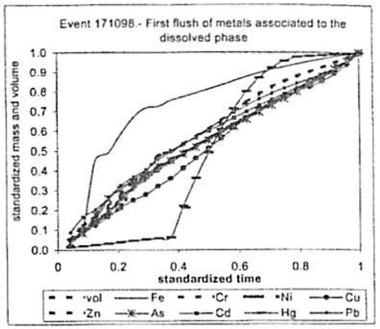


Figura nº 7

Figura nº 8

From figure no. 6 we can see that only the As and Hg are partially associated with the dissolved phase of the existing solids, whereas the other metals such as Pb, Cd, Zn, Cu and Cr are especially linked to the particulate mass. Of the 11 events analysed, two other were tested for metals associated with the different phases. The results for As were: $f_{dissolved}=0.3$ and 0.2, Hg: $f_{dissolved}=0.02$, 0.02; for the other metals: $f_{dissolved} < 0.2$. So it clearly seems that metals appear to be associated to the particulate phase of solids.

In figure no. 5 it is important to note that the SS have a more intense first flush phenomenon than the DS. This can also be applied to figures 7 and 8, where it is clear that the metals associated with the particulate phase show a more pronounced first flush efect than the dissolved metals.

Event 16/9/99

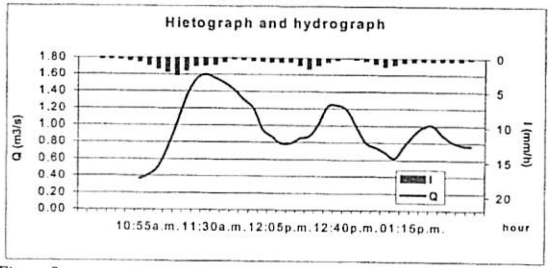
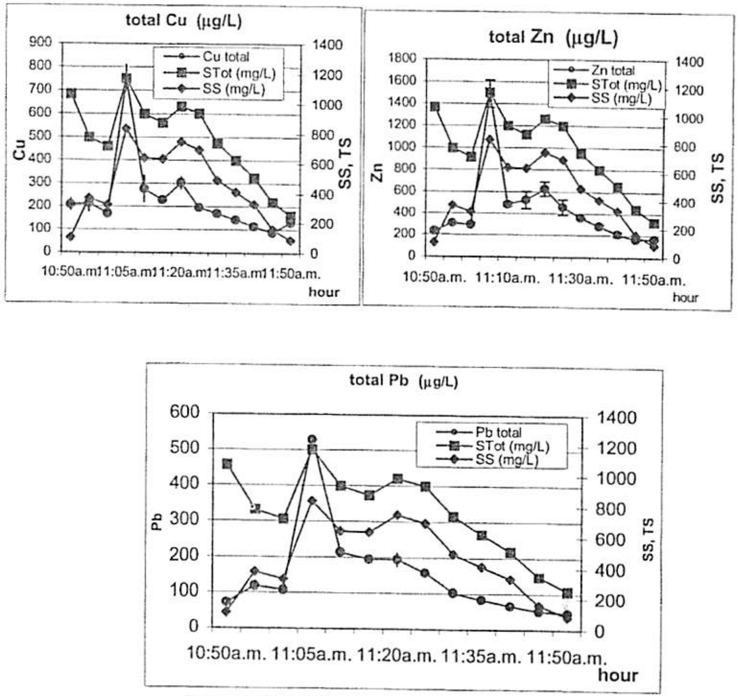


Figure 9



Figures nº 10-11-12

Figures n°s. 10-12 clearly show how the metals accompany the SS from the beginning, and not the DS, which had already been discharged earlier with the first splashing of the raindrops.

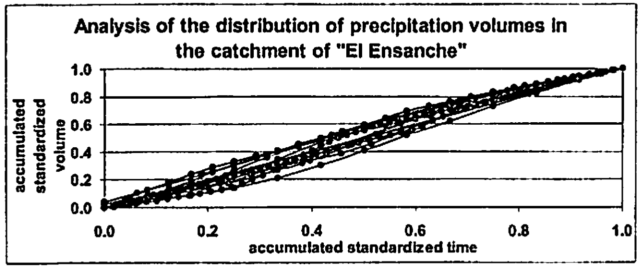


Figure n° 13

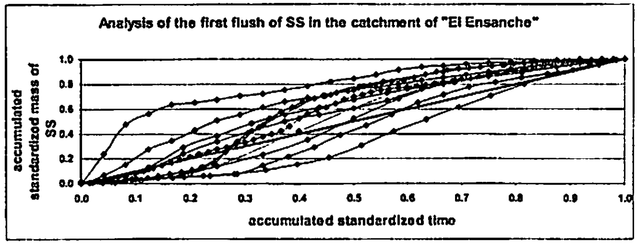


Figure n° 14

In figure 13 we can observe that the hydraulic behaviour of the catchment is very homogeneous. In figure no. 14, however, there is a more disperse and variable process in terms of the release of the solids, with a tendency towards the phenomenon of the first flush (curves above the diagonal line).

STATISTICAL ANALYSIS

The statistical analysis, in this case based on hydrological and pollutant data from an urban catchment, allows us to establish relationships between the parameters observed and the behaviour trends that will help to improve our interpretation of the physical and chemical phenomenas governing the system.

The preliminary analysis stage was conducted using a population size sample of eleven experiments representing the storm events that occurred in the catchment under study. These rainfall episodes are separated in time so that it is possible to consider the hypothesis of independence between the measurements of the study variables.

This article presents a correlation study among all the previously defined variables or parameters, examining them in pairs by means of a correlation matrix, where this coefficient has been estimated using a Pearsonian estimator. Based on the hypothesis of normality put forth, we calculated the probability that the correlation estimator would be less than the predicted value by means of the sampling carried out. This probability value takes into account the size of the sample. This probability, called level "p" or significance, allows us to evaluate the degree of confidence on the linear adjustment and to estimate the possible linear interdependence between each pair of variables. The lower the "p" level is, the better the adjustment will be and vice-versa. This information is very useful when studying the physical problem, although, in itself, has little practical value.

Before presenting the correlation matrix (table no. 3), we would like to mention that for the statistical analysis the SPSS software package was used. These types of studies are a good tool to be used in examining trends and reaching conclusions on the formal aspects of physical systems which have been idealised and modelled. It is essential, however, to use good judgement in determining the behaviour of the variables that govern the systems under consideration.

In view of the correlation matrix the following patterns are noteworthy:

1. The **Imax** events pertain to those having the greatest **Imed**, which confirms the statement above regarding the homogenous distribution of the volumes of water during storm events.
2. The greater the **Qmax**, the greater the **Qmed** will be, which confirms point 1.
3. The greater the storm water volume value (high Vw), the greater the **CMS**$_{DS}$, will be with the corresponding increase in conductivity.
4. The greater the Mss (SS mobilised mass), the greater the **CMS**$_{SD}$ will be.
5. The greater the DTSP, the greater the **CMS**$_{SS}$ will be.
6. The greater the Vw, the lesser the **CMS**$_{SS}$ will be, which indicates that storm events generally completely consume the washoff process of the accumulated surface pollution during the dry periods.
7. The greater the Vw, the greater the mobilised SS mass (Mss) will be.
8. The Qmax events show high levels of **Mss**, which confirms sections 1 and 7.
9. The high CMSss events, have high **SSmax**.
10. The events with high levels of Qmax and Qmed have high mean and maximum mass fluxs, **Qss**$_{med}$ y **Qss**$_{max}$, which confirms section 8.
11. The **CMSzn** correlates positively with the CMSss, Mss$_{med,max}$, and the CMS cu,pb,$_{COT}$; and negatively with D.
12. The **CMScu** correlates positively with the Imed, CMSss and the CMSzn,pb,$_{COT}$; and negatively with D.
13. The**CMSpb** correlates positively with the Imed, CMSss, CMSzn,cu,$_{COT}$, and negatively with D.
14. **CMS**$_{COT}$ correlates positively with CMSss and CMScu,zn,pb; and negatively with D.

FUTURE RESEARCH

After analysing the data on the dependence of the variables and their physical significance and in view of the dependence observed in the correlation graphs, we will study possible models of linear adjustments through an iteration process whereby the most representative "logical" variables, in terms of statistics, are added to the model, step by step. Based on the results, the curves will be fit considering the most developed

Correlations

		P	Imax	Imed	D	DTSP	Vw	Mss	Qmax	Qmed	CMSss	CMSds	Ssmax	Qss max	Qss med	CMSzn	CMScu	CMSpb	CMStoc	Cmed	Cmax
P	Pearsonian correl.coef.	1.00	0.27	-0.15	0.80	-0.12	0.71	0.36	-0.06	-0.31	-0.45	0.93	-0.32	-0.46	-0.59	-0.21	-0.23	-0.31	-0.28	0.88	0.83
	Sig. (bilateral)	.	*0.424*	*0.656*	*0.003*	*0.734*	*0.014*	*0.280*	*0.858*	*0.357*	*0.163*	*0.006*	*0.335*	*0.150*	*0.054*	*0.621*	*0.615*	*0.448*	*0.537*	*0.004*	*0.011*
Imax	Pearsonian correl.coef.	0.27	1.00	0.73	-0.20	0.10	-0.31	-0.24	-0.35	-0.38	0.48	0.27	0.38	-0.23	-0.03	0.37	0.50	0.45	0.43	-0.24	-0.18
	Sig. (bilateral)	*0.424*	.	*0.010*	*0.557*	*0.766*	*0.346*	*0.482*	*0.268*	*0.253*	*0.138*	*0.607*	*0.250*	*0.495*	*0.922*	*0.364*	*0.257*	*0.266*	*0.340*	*0.564*	*0.672*
Imed	Pearsonian correl.coef.	-0.15	*0.73	1.00	-0.54	-0.11	-0.59	-0.55	-0.32	-0.22	0.42	-0.07	0.15	-0.19	0.10	0.51	0.78	0.72	0.45	-0.33	-0.27
	Sig. (bilateral)	*0.656*	*0.010*	.	*0.086*	*0.744*	*0.056*	*0.077*	*0.335*	*0.511*	*0.197*	*0.899*	*0.656*	*0.573*	*0.762*	*0.193*	*0.039*	*0.045*	*0.313*	*0.420*	*0.523*
D	Pearsonian correl.coef.	**0.80	-0.20	-0.54	1.00	-0.09	0.79	0.49	0.08	-0.19	-0.53	0.59	-0.39	-0.33	-0.50	-0.62	-0.76	-0.66	-0.64	0.72	0.69
	Sig. (bilateral)	*0.003*	*0.557*	*0.086*	.	*0.792*	*0.004*	*0.126*	*0.806*	*0.577*	*0.095*	*0.216*	*0.233*	*0.325*	*0.117*	*0.102*	*0.047*	*0.077*	*0.119*	*0.045*	*0.056*
DTSP	Pearsonian correl.coef.	-0.12	0.10	-0.11	-0.09	1.00	-0.30	0.12	-0.33	-0.38	0.64	0.10	0.50	0.09	0.11	0.16	-0.04	0.28	0.23	-0.12	-0.06
	Sig. (bilateral)	*0.734*	*0.766*	*0.744*	*0.792*	.	*0.377*	*0.725*	*0.316*	*0.250*	*0.035*	*0.855*	*0.116*	*0.796*	*0.749*	*0.709*	*0.937*	*0.501*	*0.613*	*0.785*	*0.889*
Vw	Pearsonian correl.coef.	*0.71	-0.31	-0.59	**0.79	-0.30	1.00	0.77	0.55	0.32	-0.64	0.81	-0.53	0.05	-0.16	-0.23	-0.48	-0.61	-0.47	0.76	0.69
	Sig. (bilateral)	*0.014*	*0.346*	*0.056*	*0.004*	*0.377*	.	*0.005*	*0.078*	*0.339*	*0.034*	*0.051*	*0.091*	*0.881*	*0.635*	*0.581*	*0.281*	*0.112*	*0.287*	*0.028*	*0.056*
Mss	Pearsonian correl.coef.	0.36	-0.24	-0.55	0.49	0.12	**0.77	1.00	0.73	0.52	-0.13	0.89	-0.26	0.42	0.36	0.00	-0.30	-0.38	-0.22	0.69	0.65
	Sig. (bilateral)	*0.280*	*0.482*	*0.077*	*0.126*	*0.725*	*0.005*	.	*0.011*	*0.102*	*0.704*	*0.018*	*0.448*	*0.200*	*0.271*	*0.999*	*0.509*	*0.355*	*0.643*	*0.058*	*0.078*
Qmax	Pearsonian correl.coef.	-0.06	-0.35	-0.32	0.08	-0.33	0.55	*0.73	1.00	0.95	-0.23	0.88	-0.45	0.64	0.65	0.22	0.01	-0.17	-0.10	0.21	0.17
	Sig. (bilateral)	*0.858*	*0.268*	*0.335*	*0.806*	*0.316*	*0.078*	*0.011*	.	*0.000*	*0.492*	*0.020*	*0.167*	*0.033*	*0.029*	*0.606*	*0.990*	*0.694*	*0.837*	*0.621*	*0.681*
Qmed	Pearsonian correl.coef.	-0.31	-0.38	-0.22	-0.19	-0.38	0.32	0.52	**0.95	1.00	-0.18	0.37	-0.41	0.66	0.72	0.21	0.06	-0.15	-0.03	-0.15	-0.20
	Sig. (bilateral)	*0.357*	*0.253*	*0.511*	*0.577*	*0.250*	*0.339*	*0.102*	*0.000*	.	*0.593*	*0.472*	*0.214*	*0.027*	*0.013*	*0.621*	*0.900*	*0.723*	*0.942*	*0.715*	*0.642*
CMSss	Pearsonian correl.coef.	-0.45	0.48	0.42	-0.53	*0.64	*-0.64	-0.13	-0.23	-0.18	1.00	-0.22	0.73	0.36	0.54	0.69	0.66	0.82	0.78	-0.45	-0.40
	Sig. (bilateral)	*0.163*	*0.138*	*0.197-*	*0.095*	*0.035*	*0.034*	*0.704*	*0.492*	*0.593*	.	*0.679*	*0.010*	*0.280*	*0.069*	*0.060*	*0.107*	*0.013*	*0.037*	*0.265*	*0.322*
CMSds	Pearsonian correl.coef.	**0.93	0.27	-0.07	0.59	0.10	0.81	*0.89	*0.88	0.37	-0.22	1.00	0.00	0.38	0.03	0.14	-0.07	-0.09	-0.24	0.98	0.98
	Sig. (bilateral)	*0.006*	*0.607*	*0.899*	*0.216*	*0.855*	*0.051*	*0.018*	*0.020*	*0.472*	*0.679*	.	*1.000*	*0.460*	*0.953*	*0.787*	*0.897*	*0.862*	*0.653*	*0.003*	*0.003*
Ssmax	Pearsonian correl.coef.	-0.32	0.38	0.15	-0.39	0.50	-0.53	-0.26	-0.45	-0.41	*0.73	0.00	1.00	0.30	0.16	0.28	0.19	0.40	0.56	-0.31	-0.30
	Sig. (bilateral)	*0.335*	*0.250*	*0.656*	*0.233*	*0.116*	*0.091*	*0.448*	*0.167*	*0.214*	*0.010*	*1.000*	.	*0.364*	*0.643*	*0.498*	*0.679*	*0.320*	*0.187*	*0.448*	*0.476*
Qss max	Pearsonian correl.coef.	-0.46	-0.23	-0.19	-0.33	0.09	0.05	0.42	*0.64	*0.66	0.36	0.38	0.30	1.00	0.83	0.61	0.28	0.30	0.33	-0.20	-0.25
	Sig. (bilateral)	*0.150*	*0.495*	*0.573*	*0.325*	*0.796*	*0.881*	*0.200*	*0.033*	*0.027*	*0.280*	*0.460*	*0.364*	.	*0.001*	*0.112*	*0.537*	*0.469*	*0.474*	*0.632*	*0.557*
Qss med	Pearsonian correl.coef.	-0.59	-0.03	0.10	-0.50	0.11	-0.16	0.36	*0.65	*0.72	0.54	0.03	0.16	**0.83	1.00	0.62	0.44	0.38	0.38	-0.47	-0.44
	Sig. (bilateral)	*0.054*	*0.922*	*0.762*	*0.117*	*0.749*	*0.635*	*0.271*	*0.029*	*0.013*	*0.069*	*0.953*	*0.643*	*0.001*	.	*0.104*	*0.327*	*0.356*	*0.394*	*0.242*	*0.276*
CMSzn	Pearsonian correl.coef.	-0.21	0.37	0.51	-0.62	0.16	-0.23	0.00	0.22	0.21	0.69	0.14	0.28	0.61	0.62	1.00	0.87	0.87	0.65	-0.20	-0.23
	Sig. (bilateral)	*0.621*	*0.364*	*0.193*	*0.102*	*0.709*	*0.581*	*0.999*	*0.606*	*0.621*	*0.050*	*0.787*	*0.498*	*0.112*	*0.104*	.	*0.011*	*0.005*	*0.113*	*0.700*	*0.662*
CMScu	Pearsonian correl.coef.	-0.23	0.50	*0.78	*-0.76	-0.04	-0.48	-0.30	0.01	0.06	0.66	-0.07	0.19	0.28	0.44	*0.87	1.00	0.95	0.81	-0.43	-0.46
	Sig. (bilateral)	*0.615*	*0.257*	*0.039*	*0.047*	*0.937*	*0.281*	*0.509*	*0.990*	*0.900*	*0.107*	*0.897*	*0.679*	*0.537*	*0.327*	*0.011*	.	*0.001*	*0.026*	*0.472*	*0.435*
CMSpb	Pearsonian correl.coef.	-0.31	0.45	*0.72	-0.66	0.28	-0.61	-0.38	-0.17	-0.15	*0.82	-0.09	0.40	0.30	0.38	**0.87	**0.95	1.00	0.76	-0.31	-0.29
	Sig. (bilateral)	*0.448*	*0.266*	*0.045*	*0.077*	*0.501*	*0.112*	*0.355*	*0.694*	*0.723*	*0.013*	*0.862*	*0.320*	*0.469*	*0.356*	*0.005*	*0.001*	.	*0.047*	*0.544*	*0.575*
CMStoc	Pearsonian correl.coef.	-0.28	0.43	0.45	-0.64	0.23	-0.47	-0.22	-0.10	-0.03	*0.78	-0.24	0.56	0.33	0.38	0.65	*0.81	*0.76	1.00	-0.73	-0.83
	Sig. (bilateral)	*0.537*	*0.340*	*0.313*	*0.119*	*0.613*	*0.287*	*0.643*	*0.837*	*0.942*	*0.037*	*0.653*	*0.187*	*0.474*	*0.394*	*0.113*	*0.026*	*0.047*	.	*0.164*	*0.080*
Cmed	Pearsonian correl.coef.	**0.88	-0.24	-0.33	*0.72	-0.12	*0.76	0.69	0.21	-0.15	-0.45	**0.98	-0.31	-0.20	-0.47	-0.20	-0.43	-0.31	-0.73	1.00	0.98
	Sig. (bilateral)	*0.004*	*0.564*	*0.420*	*0.045*	*0.785*	*0.028*	*0.058*	*0.621*	*0.715*	*0.265*	*0.003*	*0.448*	*0.632*	*0.242*	*0.700*	*0.472*	*0.544*	*0.164*	.	*0.000*
Cmax	Pearsonian correl.coef.	*0.83	-0.18	-0.27	0.69	-0.06	0.69	0.65	0.17	-0.20	-0.40	**0.98	-0.30	-0.25	-0.44	-0.23	-0.46	-0.29	-0.83	**0.98	1.00
	Sig. (bilateral)	*0.011*	*0.672*	*0.523*	*0.056*	*0.889*	*0.056*	*0.078*	*0.681*	*0.642*	*0.322*	*0.003*	*0.476*	*0.557*	*0.276*	*0.662*	*0.435*	*0.575*	*0.080*	*0.000*	.

** The correlation is significant at the 0.01 level (bilateral)

* The correlation is significant at the 0.05 level (bilateral)

Table n° 3

models for approach. It should also be noted that because of the small number of experiments comprising the sample, the parsimony principle will be used in the analysis. (This aspect will be improved with increased fieldwork in an attempt to cover the entire range of variation in the variables). Lastly, there will be a comparison of the conclusions from the research done on this combined catchment with other similar studies conducted on a separative type catchment in the same city.

CONCLUSIONS

The most important conclusions of this article are:

- In view of the results of the CMS (event mean concentration) of the heavy metals in "El Ensanche", and after comparing NURP values (1983, ASCE 1992), we can state that the catchment generates high values of: Cu (x 4.7 the NURP value) and Zn (x 1.8); and on a slightly lower scale Pb (x 0.73).
- From a hydrological point of view, the catchment behaves homogeneously in terms of volume distribution on the hydrograms depicting storm events,.
- As regards the pollutant mass mobilised during the rainy weather, we would like to point out that: a) the SS are the main vector of pollution, particularly of the heavy metals Cu, Zn and Pb, in addition to TOC; b) the previous dry spell has a positive effect on the SS mass mobilised; c) the storm events generally use up the whole surface accumulated mass through the washoff process, d) the SS have a stronger first flush effect than the DS, and therefore, in a similar way, do the metals associated with the particulate phase; and e) the heavy metals, Zn, Cu, Pb and the TOC are present at the same time and the intensity of the precipitation has a positive influence on the concept of the minimum energy needed to mobilise these pollutants.

BIBLIOGRAPHIC REFERENCES

CAGIAO, J.; DÍAZ-FIERROS, F.; JÁCOME, A.; PUERTAS, J.; SUÁREZ, J.; (1998); "The early stages in the CSO characteristisation in the city of Santiago de Compostela (Spain)"; UDM '98; Fourth International Conference on Developments in Urban Drainage Modelling; 21-24 september; IAWQ, IAHR, UNESCO, vol. 2; pag. 643-648.

CAGIAO, J.; PUERTAS, J.; JACOME A.; SUAREZ, J.; (1999); " Water quality simulation during CSO events in an urban catchment of the North of Spain"; ICUSD99; International Conference on Urban Storm Drainage, Sydney-Australia.

DRAPER; (1998); "Applied Regression Analysis"; Ed. Wiley-Interscience.

OTV (1994); "Depolluer les eaux pluviales. Contribution a lélaboration dúne stratégie." Lavoisier TEC & DOC, Francia, 350 págs., ISBN 2-87777-417-1.

SEBER; (1984); "Multivariate observations"; Ed. John Wiley & Sons.

TEMPRANO, J.; SUÁREZ, J.; TEJERO, J.I.; (1998); "Dimensioning criteria for storm water tanks for Santander. The case of ocean combined sewer overflow discharge"; European Water Management; pag. 55-60, volume 1, n° 4, EAWPCA; ISSN 1461-6971.