

QUANTITATIVE AND QUALITATIVE ANALYSIS OF STORM WATER RUNOFF IN AN URBAN EXPERIMENTAL CATCHMENT

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1. INTRODUCTION

During the last twenty years millions of dollars have been invested in new wastewater treatment facilities to control water pollution. Despite this effort, many streams are still plagued with pollution. The main reason is due to storm water pollution runoff, because the storm water is characterized by a similar quality like the wastewater of civil and productive origin, both in terms of maximum concentration and of polluting mass.

When the water drops cross the atmosphere, they absorb the substances there present, and if the atmosphere is polluted, the rain receives these pollutants (suspended solids, organic substances, nitrogen, phosphorus, chlorides, etc.). The average contribution from the atmospheric pollution is around 25%

When the rain falls onto the soil it washes the surfaces of the catchment, removing the pollutants that have been accumulated on the surfaces in the previous dry period.

The contribution of contamination of the impervious areas is highly tied to traffic (like copper, chrome, lead and nickel); solid and liquid wastes, salt spillages in the winter periods, oil and fuel spillages, vehicle derived wastes including those from tire and brake lining wear, paint residual (such as roofs, building surfaces and road markings) and road-surfacing products (like bitumen and asphalt).

Agricultural activities are an important source of pollution of the water runoff of permeable surfaces. Such pollution is due to the diffused use of insecticides, herbicides and fertilizers.

A further contamination of the storm water runoff occurs into the drainage systems where, for high intensity of precipitation, the runoff takes the sediments present in suspension.

The different sources of pollution and the dynamics with which the water runoff is loaded with pollutants make this problem very complex.

From the beginning of the 1970s the research related to the storm water pollution started to define the contributions of pollutants to the storm water runoff, the load of pollutants and the kind of pollutants present.

In Italy, since 1980 about ten experimental urban catchments have been equipped for runoff quality monitoring studies, and later for some of these, the investigation has been extended also to quality data.

The Cascina Scala experimental urban catchment has been functioning since 1989. It is situated in the north of Pavia (region Lombardia-Italy). This catchment has been equipped initially for runoff quantity monitoring studies. Since 2000 the investigation has been extended also to quality data.

2. DESCRIPTION OF THE EXPERIMENTAL CATCHMENT

The catchment where the investigation is in progress is located at a residential district in northern Pavia. This is a peripheral district, separated from the rest of the city and it is hydrologically well defined.

Figure 1 shows the location of Cascina Scala in Italy and figure 2 shows a map of the experimental catchment.

Cascina Scala is an urban catchment of exclusively residential use. The population was around 1300 inhabitants in April 2001. The contributing area was 113480 m² with 65% of impervious areas (roofs, parking, streets and paved surfaces) while 35% of the area was pervious (public and private gardens) and was not connected to the sewer system. The catchment is drained by a combined sewerage network. It has a total length of 2045 m and a slope of 0.42%. More details on the physical characteristics of the basin and the drainage system are reported in another paper (Ciaponi and Papiri, 1994).

Since May 2001 the total contributing area increased by a value of 13300 m² and the population also increased by 150 people, due to construction of a new residential complex.

3. INSTRUMENTATION OF THE EXPERIMENTAL CATCHMENT

Rainfall is measured on the catchment with two tipping bucket rain gauges SIAP with a 0.2 mm resolution, which has been dynamically calibrated, and a UM 7505 precipitation sensor. The distance between the two rain gauges is 310 m, therefore the spatial uniformity of the precipitation can be checked.

The storm water runoff in the final reach of the sewer network is measured using a Venturi tube with an ISCO 4230 bubbler flowmeter. Temperature and conductivity in the final reach of the sewer network are measured on site with a YSI 600 multi-parameter sonde (every 2 minutes). Storm water runoff samples are being collected by a refrigerated automatic grab sampler (ISCO 6700 SR) equipped with 24 bottles. The sampling program is such that when the flow level reaches 120 mm the sampler is activated. In the laboratory, analyses of specific conductivity, COD, BOD₅, suspended solids, settleable solids, total nitrogen, ammonium nitrogen, phosphorus, lead, zinc and hydrocarbons, are carried out.



Figure 1: Location of the Cascina Scala (Italy) Experimental Catchment

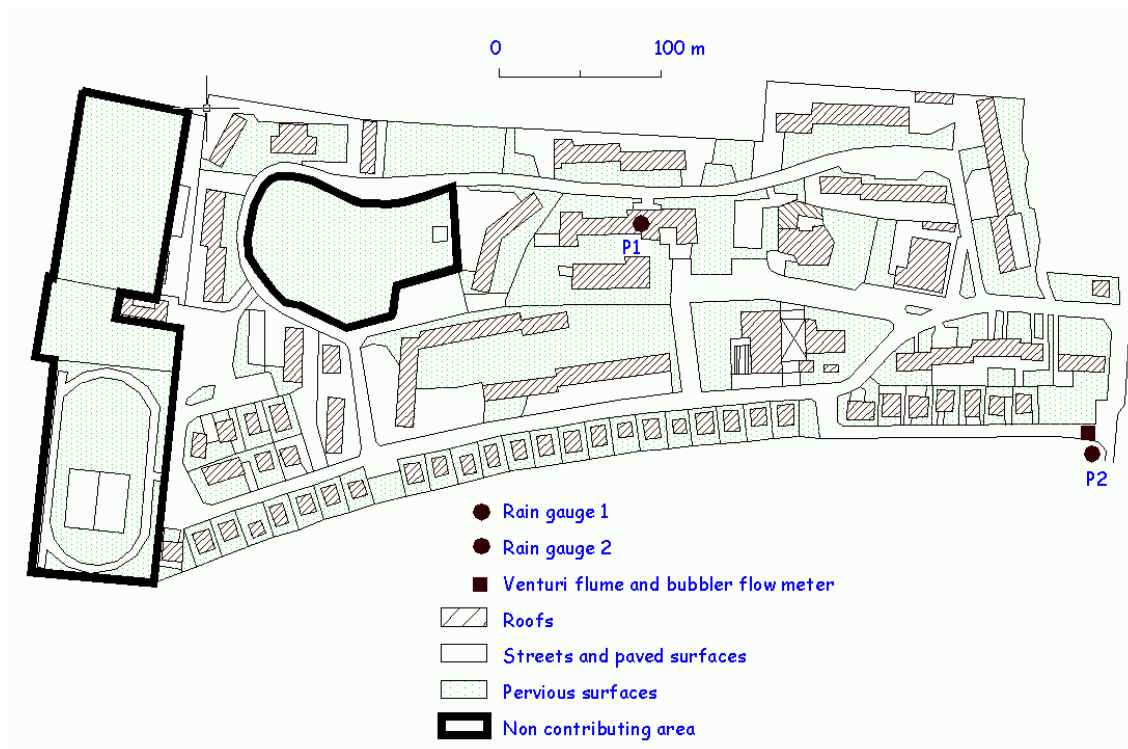


Figure 2: Map of the experimental catchment.

4. MEASUREMENT

The quantity and quality data of the drainage flows in the sewer network during wet weather had been collected in two periods: June-July 2000 and March-April 2001 [6,7]. 162 in total were collected at 14 meteorological events.

In February 2001 12 samples had been collected during dry weather, so as to cover a whole day.

Table 1 shows the main characteristics of rainfall and runoff observed during each of the 14 events of wet weather, while Table 2 reports the range and mean value of the quality parameters.

Table 3 reports the range and mean value of the quality parameters during dry weather.

Figures 3a and 3b show the hydrograph, hyetograph and pollutograph for 8 out of 14 events.

Table 1. Characteristics of the events [6,7].

Event	Date	Rainfall Length min	Rainfall Depth mm	Maximum Flow Rate l/s	Measured Volume m ³	Number of Collected Samples	Dry Time Day
1	10/06/2000	11	12.8	969 (*)	634 (*)	1	4.2
2	11/06/2000	423	35.4	939 (*)	1655 (*)	5	0.4
3	11/06/2000	197	11.8	290	452	3	0.5
4	13/06/2000	30	2.0	36	28	1	0.8
5	23/06/2000	108	16.4	553	764	18	10.8
6	28/06/2000	23	15.6	850	752	12	4.8
7	08/07/2000	50	7.0	325	232	8	3.3
8	10/07/2000	64	11.0	376	438	12	1.8
9	11/07/2000	215	10.6	190	466	4	0.9
10	13/03/2001	247	3.8	33	131	12	0.3
11	17/03/2001	478	26.2	281	1416	24	3.9
12	28/03/2001	443	18.6	263	935	24	11.0
13	10/04/2001	110	8.4	157	444	16	3.3
14	20/04/2001	380	15.8	257	861	22	0.0

(*) The sewer reaches pressure flow conditions.

Table 2. Range and mean values of the quality constituents for the 162 samples collected during storms [6,7].

Constituent	Unit of Measure	Mean Value	Minimum Value	Maximum Value
Specific Conductivity	µS/cm	220	86	747
COD	mg/l	484	28	2434
BOD ₅	mg/l	281	8	1780
Hydrocarbons	mg/l	3.87	0.13	38.40
Suspended Solids	mg/l	502	20	2360
Settleable Solids	ml/l	18.2	0.8	100.0
Total Nitrogen	mg/l	22.81	1.51	86.60
Ammonium Nitrogen	mg/l	8.36	0.45	39.60
Phosphorus	mg/l	2.70	0.22	13.10
Lead	mg/l	0.320	0.001	13.100
Zinc	mg/l	0.540	0.010	4.920

Table 3. Range and mean values of the quality constituents for the 12 samples collected during dry weather [6,7].

Constituent	Unit of Measure	Mean Value	Minimum Value	Maximum Value
Specific Conductivity	µS/cm	713	550	980
COD	Mg/l	544	146	1037
BOD ₅	Mg/l	462	125	720
Hydrocarbons	Mg/l	1.90	0.45	5.76
Suspended Solids	Mg/l	300	20	680
Settleable Solids	ml/l	33.0	<1.0	62.0
Total Nitrogen	Mg/l	43.40	27.80	99.00
Ammonium Nitrogen	Mg/l	30.80	19.50	75.00
Phosphorus	Mg/l	4.10	2.10	7.94
Lead	Mg/l	0.040	0.013	0.150
Zinc	Mg/l	0.400	0.100	0.740

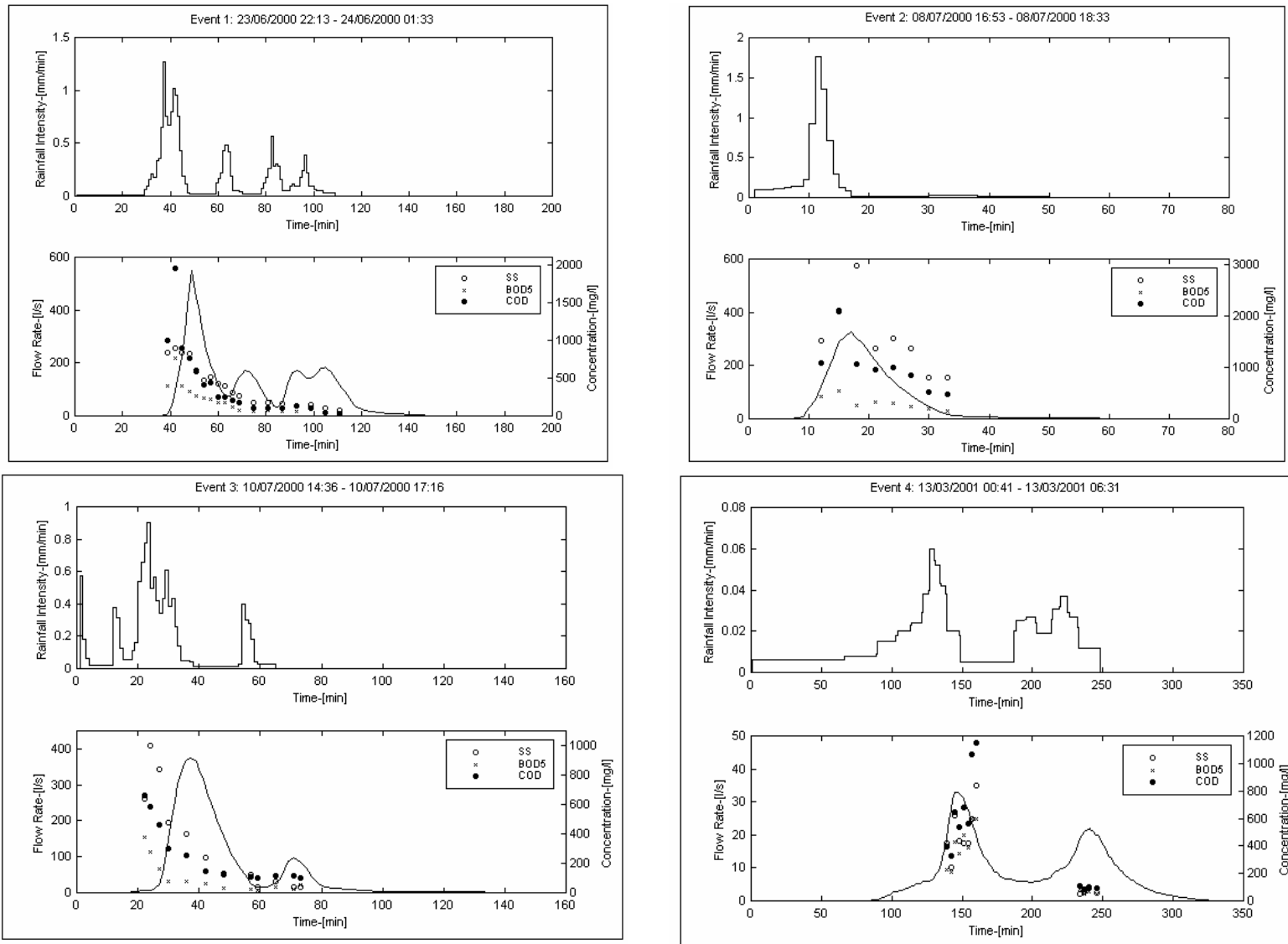


Figure 3a: Hydrograph, hyetograph and pollutograph for 8 out of 14 In cascina Scala (Pavia)

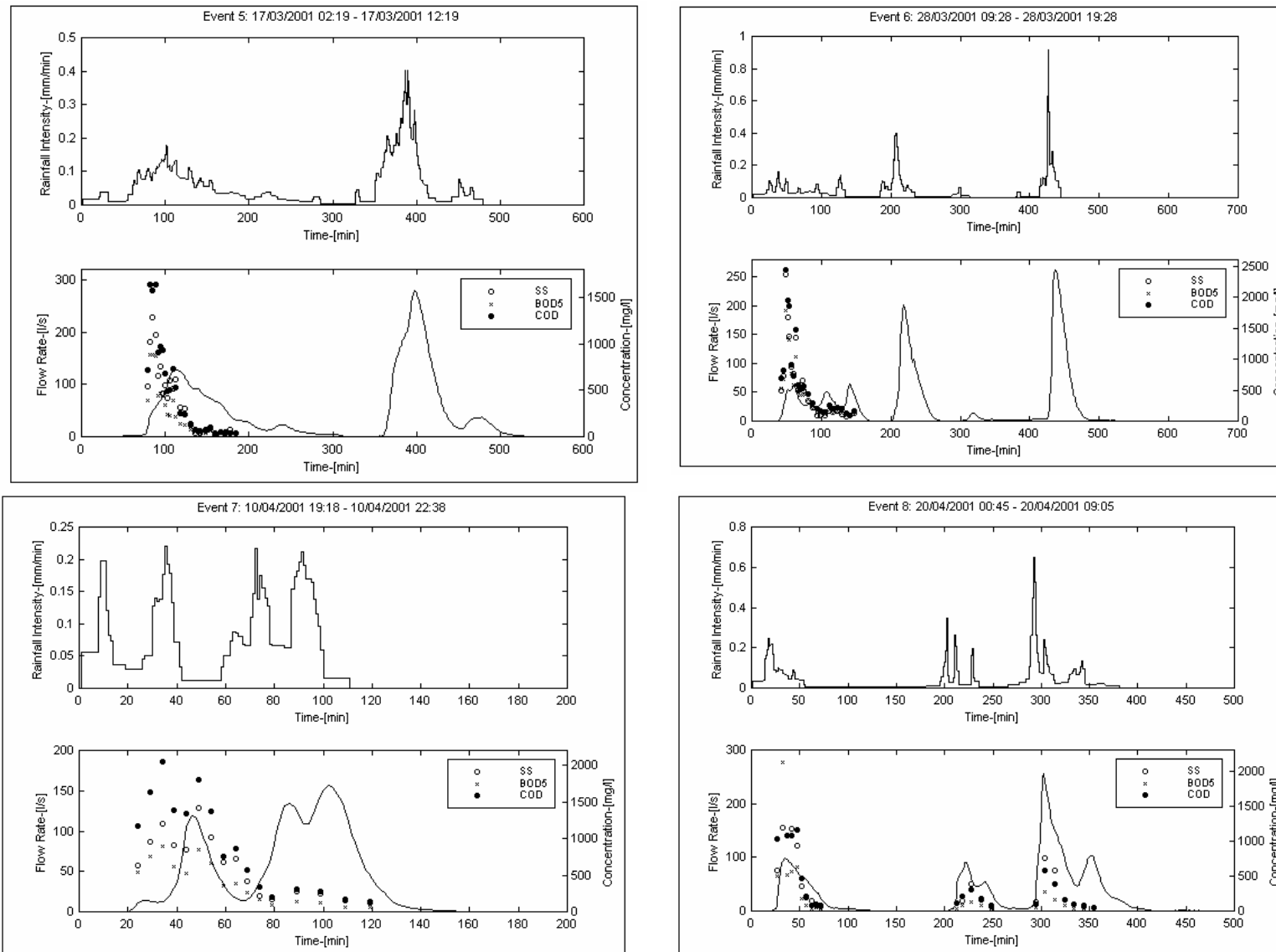


Figure 3b: Hydrograph, hietograph and pollutograph for 8 out of 14 In cascina Scala (Pavia)

5. QUALITY DATA ANALYSES OF STORM WATER RUNOFF

The main parameters that contribute to the majority of water quality problems in urban catchments are: Suspended solids because it is a general indicator of pollution, COD and BOD₅ because they supply a relative indication of the organic pollution. Besides, they are assumed as a reference parameter in many mathematical models simulating the pollutants dynamics during storm water runoff.

Comparing the values reported in the Tables 2 and 3, it can be observed that the fluctuations of the values of suspended solids, COD and BOD₅ during wet weather are more noticeable than during dry weather. The maximum values of the constituents during wet weather are greater than during those corresponding to dry weather.

Correlation analyses have been searched between suspended solids with COD and BOD₅. For the first measurement campaign (June-July 2000) relative to 64 samplers, the results are summarized as follows:

$$COD [mg/l] = 0.776 SS [mg/l] \quad \text{Coefficient correlation } R = 0.86$$

$$BOD_5 [mg/l] = 0.312 SS [mg/l] \quad \text{Coefficient correlation } R = 0.77$$

For the second campaign (March-April) relative to 98 samplers, the results are the following:

$$COD [mg/l] = 1.328 SS [mg/l] \quad \text{Coefficient correlation } R = 0.95$$

$$BOD_5 [mg/l] = 0.715 SS [mg/l] \quad \text{Coefficient correlation } R = 0.95$$

These results confirm the existence of a high correlation between the BOD₅, COD and suspended solids concentration in urban storm water runoff. However, the concentrations are different for the samples of the two campaigns.

Ciaponi et. al. [7] have explained that these statistical differences are due to the external factors of the catchment-drainage system. For example, the different characteristics of the precipitation and the different temperatures that influence the degradation kinetics of the pollutants.

The number of samples that have been taken strongly vary for each event. The sampler condition was programmed so as to depend on a fixed minimum water level in the final reach of the sewer network. Therefore an adequate number of samples had been gathered only for events with a certain precipitation intensity.

Figures 3a, 3b and Table 1 confirm the dependence of the pollutograph on the hyetograph (in particularly intensity and previous dry period).

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