Evaluation of the Pollutant Content in Road Run-Off First Flush Waters

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SYNOPSIS

Road runoff waters are able to convey a number of organic and inorganic pollutants originated by different non point sources and by the road surface itself. Such pollutants can enter aquatic systems, thus contributing to water and soil contamination. This study was aimed at evaluating the pollutant content in first flush runoff waters from a highway located in Central Italy. A water sampling apparatus was devised able to collect only the first 10 litres of runoff water. Water samples were analyzed by atomic absorption spectroscopy, ion chromatography, and gas chromatography-mass spectrometry in order to determine metals, ions, and polynuclear aromatic hydrocarbons, respectively. Soil samples were collected as well for metal and hydrocarbon determination. Results obtained in a field experiment carried out in two different seasons and in two different sites along the highway are reported. The study was extended to water samples collected in a strip of the same road not yet in use.

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INTRODUCTION

Road surface is characterized by the occurrence of a number of pollutants, i.e. suspended solids, heavy metals and hydrocarbons, originated by a wide range of non-point sources like wet and dry deposition, vehicle exhausts, vehicle and road wear, de-icing operations, accidents, and soil erosion.

For example, hydrocarbons are present in oil and fuel exhausts. Metal are present in fuels (lead) as well as in brake linings (copper), tyres (zinc and cadmium), safety fences (zinc), and in dry depositions (Legret and Pagotto, 1999). During the winter, antifreeze salt are a source not only for sodium, calcium, and chlorine but also for high zinc and cadmium levels, as a result of an enhancement of corrosion phenomena due to the heavy metal mobilizing effects of de-icing solutions containing sodium chloride and calcium chloride (Bauske and Goetz, 1993). The road surface itself is an important source of pollutants, since the components of asphalt, i.e. stone materials (whose content is approximately 95%) and bituminous binders (5%) release different contaminants. Bitumen contains, besides a number of hydrocarbons, trace metals like vanadium, iron, nickel, magnesium, and calcium. However, metal content in stone material is not negligible, especially considering its percent amount in asphalts (Lindgren, 1996).

All the above cited pollutants can enter aquatic systems mainly via runoff, thus contributing to water and soil contamination (Boxall and Maltby, 1995; Maltby *et al.,* 1995a; Maltby *et al.,*1995b; Perdikaki and Mason, 1999), the extent of such contamination being related to different factors, among which volume of traffic, rainfall and size of receiving waters are crucial.

There are several studies on this topic carried out in several European nations (Bertrand-Krajewski *et al.* 1998; M. Koeleman *et al.* 1999; Krein and Schorer, 2000; Legret and Pagotto 1999) and in overseas countries (Ball *et al.,* 1998; Brezonik and Stadelmann, 2002). However, in Italy such kind of investigations is lacking. Therefore, a study was conducted aimed at evaluating the content of organic and inorganic pollutants in first flush runoff waters from a highway located in Central Italy. In the following the description of a field experiment carried out in two different seasons in 2002 is reported together with the obtained results.

STUDY AREA AND SAMPLING APPROACH

The study area is a 29 km long section of the SS 73/bis, a fast flowing (speed limit 110 km h^{-1}) four-lane highway, classifiable as an extra-urban way, connecting the coastline with inland.

The average traffic volume is reported in Table 1.

Table 1: Average traffic volume on the SS 73 bis, Km 106. Data source: ANAS, Italian Road General Agency, 2002.

	Day hours 7.00 AM-7.00 PM	Night hours 7.00 PM-7.00 AM
Average number of vehicles	13169	5272
Motorcycles	1.15%	0.64%
Cars up to 8 seats	88.70%	89.60%
Vans up to 30 quintals	3.31%	3.00%
Lorries over 30 quintals	2.37%	2.20%
Truck-trailers	0.89%	1.06%
Articulated lorries	3.33%	3.16%
Motor coaches	0.24%	0.19%
Tractors	0.01%	0%

Along this road, two different sampling sites were chosen at km 78 and 107, named site 1 and 2, respectively. Area surrounding site 1 is much less industrialized with respect to the area around site 2. A further site (site 3) was recognized in a strip of the same road that is not yet in use. That with the aim of discriminating the contribute of vehicular traffic from that due to asphalt, safety fences, and atmospheric deposition. Figure 1 reports a map of the study area with the indication of the sampling sites. Sampling cans were placed in the concrete drainage ducts located on the side of the road for conveying runoff waters.

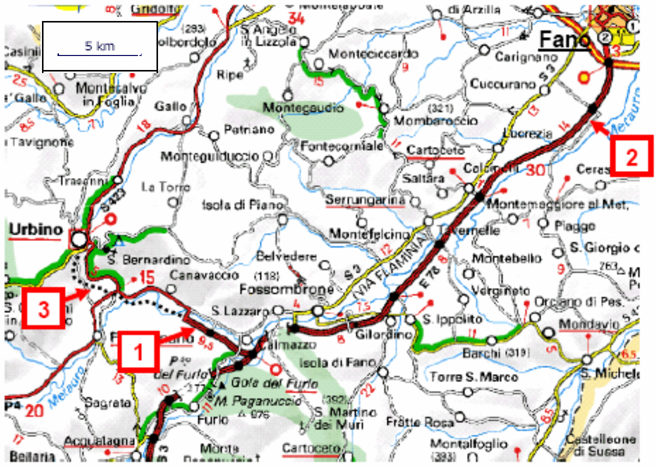

Figure 1: Map of the study area

In order to collect first flush waters a sampling apparatus was devised able to collect only the first 10 litres of runoff water. As a matter of fact, there is some discrepancy in the definition of first flush waters, with different definitions given by various authors (Bertrand-Krajewski *et al.* 1998; Stahre and Urbonas 1990; Wanielista and Yousel, 1993; Sansalone and Buchberger, 1997; Thornton and Saul 1987; Deletic, 1998) . In this study, it was decided to collect the first 10 litres of runoff water considering such a volume as representative of the storm event. Such a volume allows to assess the maximum pollutant load, and is therefore useful in establishing prevention and/or decontamination measures.

The sampling apparatus, whose schematic diagram is reported in Figure 2, is designed as follows:

- A plastic inlet tube (Tube 1) , o.d. 10 cm, equipped with a grid to prevent coarse materials from entering into the sampling apparatus;
- A polyethylene tube (Tube 2), o.d. 2 cm, connecting Tube 1 and Tube 3;
- A tube, o.d. 3 cm, (Tube 3) entering the first sampling can (Can A).
- Two High Density Poly Ethylene (HDPE) 5-litre cans (Can A and Can B), placed at a lower level with respect to the road surface, in order to convey runoff waters by gravity.
- A fourth tube (Tube 4), polyethylene, o.d. 2 cm, connecting the two cans.
- Two plastic tubes (Tube 5), o.d. 1 cm, allowing the air inside Can A and B to exit, thus avoiding the entry of discharge water after first flush. These tubes are positioned at a higher level with respect to Tube 3, so that when both cans are filled, runoff water is not allowed to enter into the cans, being discharged through Tube 3.

Runoff water goes through the first three tubes. Can A is equipped with a two port plug connected to Tube 3 and Tube 4, so that when Can A is filled, water flows though Tube 4 towards Can B. When also Can B is filled, water is discharged through Tube 3, thanks to the communicating vessels principle. After each storm event, sampling can were removed and water samples were stored at 4°C before being analyzed.

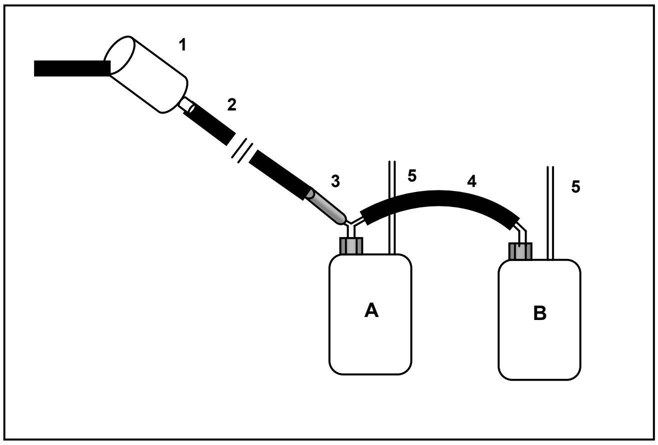

Figure 2: Schematic diagram of the sampling apparatus; for reference numbers, see text

Two different sampling campaigns were carried out: a summer campaign in August 2002, and an autumn campaign in October 2002. Surface soil samples were collected as well. In order to sample those soils directly receiving runoff waters, sample were taken close to drainage ducts in sites 1 and 2. Polyethylene tools, previously washed with a solution of nitric acid and rinsed with Milli Q water, were used. Samples were stored in polyethylene containers. In order to compare concentration data measured in those soil with background values, it was decided to collect uncontaminated soil samples in a uncultivated site far away from asphalted roads (site 4). However, it must be remembered that the pollutant content of a soil is strongly dependent on soil texture.

MATERIALS AND METHODS

Water Sample Preparation

Water samples were filtered using cellulose ester filters (Millipore Co., Billerica, MA, USA) 0.22-µm pore size, previously conditioned at 60°C and weighed. Aliquots of the aqueous fraction were then acidified with 1% of nitric acid Merck Suprapur 65% (Merck, Darmstadt Germany), and kept at 4°C before atomic adsorption spectrophotometry (AAS) analysis. Water samples were stored in 50-ml polyethylene (PE) bottles, previously conditioned with Milli Q water acidified with 10% of Merck nitric acid non Suprapur (65%), rinsed after 24 hours with Milli Q water. Standard solutions were prepared in Milli Q water for ion chromatography (IC) analysis, and in Milli Q acidified water with 0.2% of nitric acid Merck Suprapur and 2% of nitric acid Merck Suprapur for graphite oven AAS and flame AAS, respectively.

In order to determine the exact weight of the insoluble fraction 500-mL aliquots of sample were filtered. Before weighing, the filtrate was oven dried for 2 hours at the temperature of 60°C.

Aliquots of insoluble fraction were separated from water by centrifugation. The centrifuged was then frozen to -18°C and lyophilized. After lyophilizing, the insoluble fraction was weighed and then underwent acid digestion and toluene extraction for the determination of metals and polycyclic aromatic hydrocarbons (PAHs), respectively.

Acid digestion was performed in a microwave oven MDS-2100 (CEM Microwave Technology, Buckingham, UK). The following acid mixture was added to 30 mg of lyophilized sample: 8 mL nitric acid Merck Suprapur 65%, 2 mL fluoridric acid Merck Suprapur 40%, and 2 mL phosphoric acid Merck Suprapur 85%. For microwave digestion of 4 Teflon vessels, the following program was used: Power 30% ; Pressure 70 psi, Temperature 175°C; Ramp 5.5 minutes; Parameters time 4.5 minutes.

Toluene ultrasound assisted extraction was performed in three subsequent extraction cycles on 350 mg of the lyophilized fraction. The extracted was then analyzed in capillary gas chromatography coupled with quadrupole mass spectrometry (GC-MS).

A schematic diagram of the overall analytical procedure is reported in Figure 3.

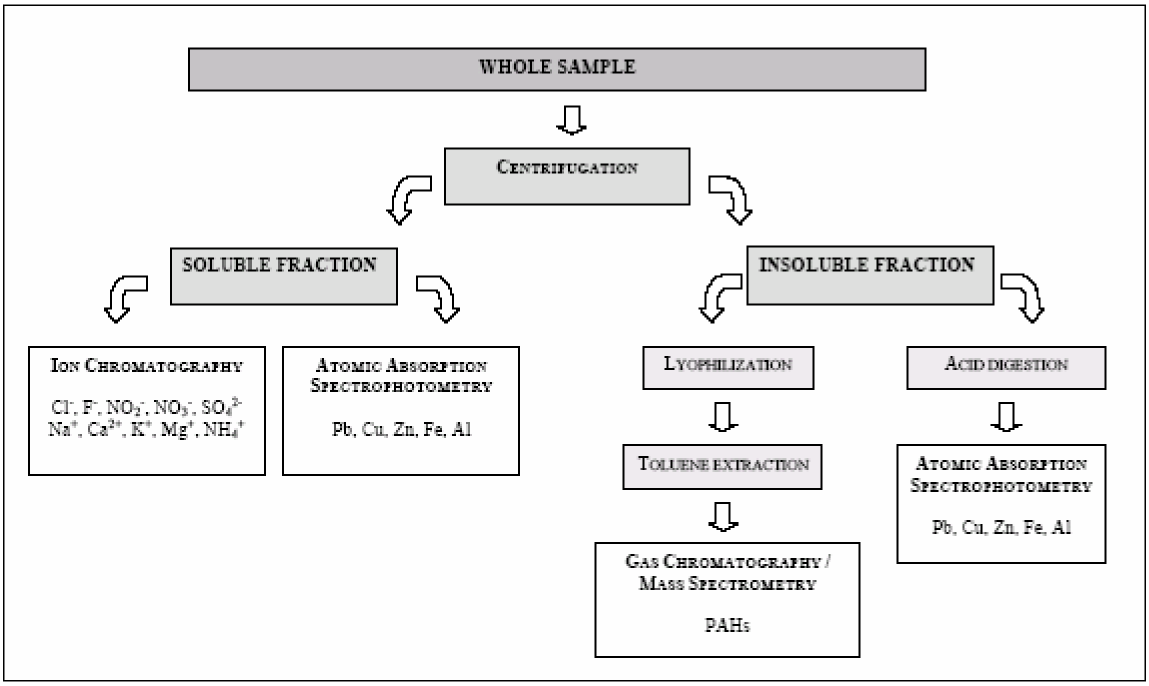

Figure 3: Schematic diagram of the overall analytical procedure

Soil Sample Preparation

Soil sample were of fluvial sandy-argillaceous type. They underwent both AAS and GC-MS analysis. Before AAS analysis, 500 mg aliquots of soil sample were lyophilized and subsequently underwent micro-wave assisted mineralization at 180°C, pressure 100 psi, for 60 minutes at 70% of power. Acid mixture used had the following composition: Milli Q water10 mL, HNO_3 suprapur 5 mL, HF suprapur 3 mL, HCl suprapur 2 mL. Final solution was diluted up to 100 mL in a polyethylene volumetric flask. For comparison purposes, aliquots of soil collected at a higher distance from the road underwent the same sample preparation procedure and were then analyzed by AAS. Soil sample to be analyzed by GC-MS were first lyophilized. Then, toluene was the solvent used for extracting the organic fraction in ultra sonic water bath.

Ion Chromatography

A Dionex DX 120 (Dionex Co., Sunnyvale, CA, USA) ion chromatograph equipped with a conductimetric detector was employed. For anion determination a Dionex IonPac AS9-HC (4x250mm) column and an IonPac AG9-HC (4x50mm) pre-column were used, with a self-regenerating ASRS-ULTRA (4mm) suppressor, using sodium carbonate-sodium bicarbonate as eluent. For cation analysis a Dionex IonPac CS12A (4x250mm) column with an IonPac CG12A (2x50mm) pre-column and a CSRS-ULTRA (4mm) cation self-regenerating suppressor were used with metanesulphonic acid as eluent.

Atomic Absorption Spectrophotometry

The instrument used was a double beam AAnalyst 300 (Perkin Elmer, Wellesley, MA, USA) equipped both with a flame atomizer, both with a graphite furnace HGA-800 type. Graphite furnace atomizer was used for the determination of Pb and Al in both soluble and insoluble fraction, and Cu in the soluble fraction only. The flame atomizer was employed for determining Zn and Fe in both fractions and Cu in the insoluble fraction.

Gas Chromatography-Mass Spectrometry

An Agilent (Agilent Technologies, Palo Alto, CA, USA) HP6890N gas chromatograph coupled to a HP5973N quadrupole mass spectrometer with electron impact (EI) ion source was employed. The MS was operated in the selected ion monitoring (SIM) mode, selecting the following m/z values subdivided in 7 acquisition windows: 128, 166, 178, 202, 228, 252, 278, 279, and 300. The capillary column was a HP5-MS (Agilent Technologies) 30 m long, 0.25 mm i.d., film thickness 0.25 μm, with the following temperature programme: 1 min at 100°C and then, at 6°C min^{-1}, up to 300°C,. UHP helium was used as carrier gas at a flow rate of 36 cm s^{-1}. Transfer line temperature 300°C, volume injected 1μL, injector temperature 290°C.

RESULTS AND DISCUSSION

Metal Analysis

Metals were determined in both soluble and insoluble fractions. Table 2 reports results obtained analyzing the soluble fraction in the two different stations in the summer and the autumn campaigns, respectively. Aluminium is by far the most abundant element measured, followed by zinc, iron, and copper. Higher concentrations were measured for all the elements in samples collected during the summer as a consequence of the rather long (12 days) dry period preceding the summer rain event. Origin of aluminium is likely to be manly natural, being Al the most abundant crust element. However, in samples collected during the autumn campaign Al concentrations are relatively less significant with respect to Fe levels. Iron has not only a crust origin but it also originates from vehicle metal corrosion and from tyres wear. Its relatively higher concentration in autumn samples suggests a higher contribution to runoff water pollution by anthropogenic activities, i.e. light and heavy vehicular traffic, less intense in August that is typically holiday time.

Table 2: Metals determined in the soluble fraction in two different campaigns. Concentrations expressed in μg L^{-1}

Element	Summer Campaign				Autumn Campaign			
	Site 1		Site 2		Site 1		Site 2	
	Can A	Can B	Can A	Can B	Can A	Can B	Can A	Can B
Al	305.76	158.48	145.52	176.85	90.02	56.24	64.82	313.80
Zn	132.95	86.08	125.30	88.00	0.00	13.00	10.00	0.00
Fe	50.87	29.35	76.31	39.13	101.00	93.00	95.00	96.00
Cu	85.93	6.33	10.20	28.29	13.91	18.26	18.47	15.00
Pb	1.11	3.70	2.50	3.77	0.00	0.00	0.00	0.00

Anyhow, all the elements, being mainly emitted in a particulate form, pertain to the insoluble fraction where much higher concentrations of all the elements were measured, as it can be seen in Table 3, where the amount of the different elements expressed in μg per g of suspended particulate matter in each sample is given. Al e Fe are again the most abundant elements. Also in this case, concentrations measured in autumn are lower with Fe concentration levels relatively more significant.

Pb is below detection limits in the soluble fraction and scarce in the insoluble fraction as a logical consequence of the elimination of leaded gasoline in Italy since January 2002. Lead measured in the insoluble fraction is ascribable to tyres and asphalt wear, and is therefore emitted as particulate matter. Brake wear is likely to be the major source for the copper detected in all the samples (Legret and Pagotto, 1999).

Table 3: Metals determined in the insoluble fraction in two different campaigns. Concentrations expressed in $\mu g\ g^{-1}$

Element	Summer Campaign				Autumn Campaign			
	Site 1		Site 2		Site 1		Site 2	
	Can A	Can B	Can A	Can B	Can A	Can B	Can A	Can B
Al	17508.74	48108.57	30755.85	33235.79	45588.93	14798.28	6303.03	28337.91
Zn	1948.98	2930.00	1459.04	1087.36	1617.45	2239.66	1639.73	1354.47
Fe	22250.00	32305.00	14185.03	18497.70	25300.34	32205.17	22035.35	18145.20
Cu	491.50	588.33	255.65	187.36	325.50	513.79	254.21	192.94
Pb	247.57	277.46	274.12	209.86	151.73	176.95	156.28	156.76

Data reported Table 3 show that particulate fractions collected in site nr 2, closer to the industrialized area, are less polluted in terms of metal content. However, when concentrations measured are referred to the volume of water collected, a different situation emerges. In fact, the amount of the particulate matter weighed in samples collected in site nr 2 is much higher than that collected in site 1, as reported in Table 4.

Table 4: Amount of particulate matter (g) weighed in 1 litre of water sample

Summer				Autumn			
Site 1		Site 2		Site 1		Site 2	
A	B	A	B	A	B	A	B
0,080	0,045	0,254	0,592	0,021	0,010	0,096	0,224

Table 5 reports element concentration levels in the insoluble fraction expressed in μg of each metal per litre of sample, with site nr. 2 more polluted with respect to the other sites, as a consequence of heavy traffic related to industrial activities and possibly to industrial emissions themselves.

Table 5: Metals determined in the insoluble fraction in two different campaigns. Concentrations expressed in $\mu g\ L^{-1}$

Element	Summer Campaign				Autumn Campaign			
	Site 1		Site 2		Site 1		Site 2	
	Can A	Can B	Can A	Can B	Can A	Can B	Can A	Can B
Al	1393.70	2184.13	7811.99	19675.59	966.49	153.90	605.09	6336.36
Zn	155.14	133.02	370.60	643.71	34.29	23.29	157.41	302.86
Fe	1771.10	1466.65	3603.00	10950.64	536.37	334.93	2115.39	4057.27
Cu	39.12	26.71	64.94	110.91	6.90	5.34	24.40	43.14
Pb	19.71	12.60	69.63	124.23	3.22	1.84	15.00	35.05

Distribution of the different elements between the soluble and insoluble fractions are reported in Figure 4 that clearly shows that the most important contribution to the total metal load of each element is given by the insoluble fraction.

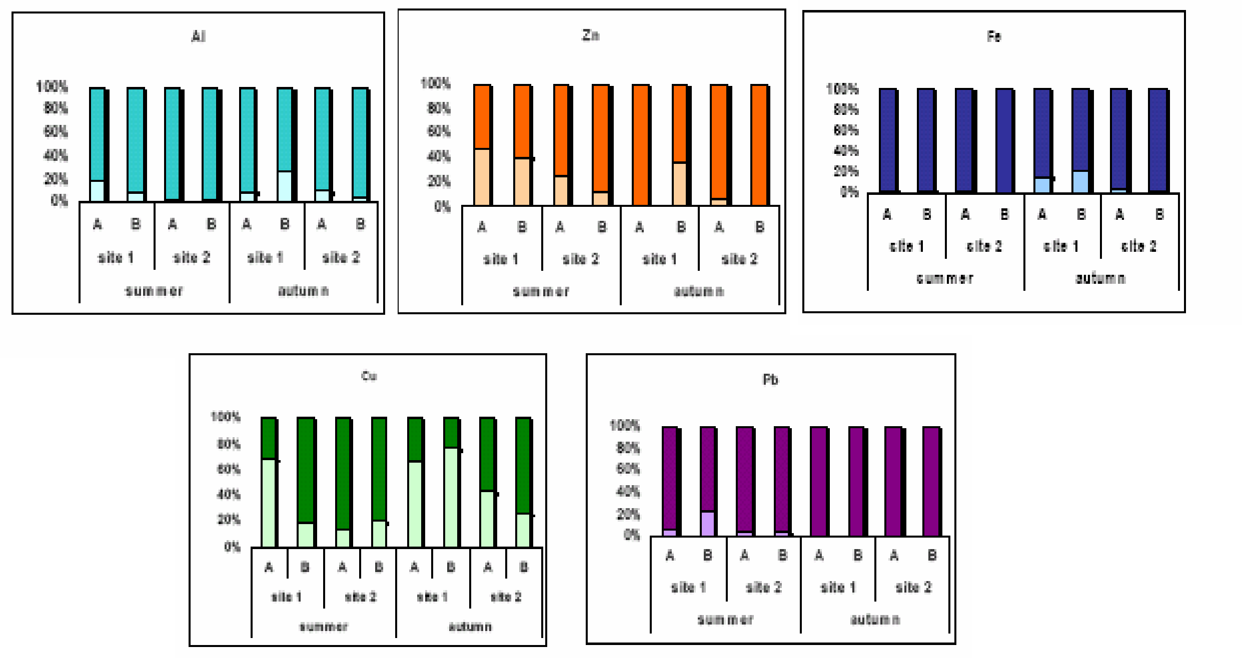

Figure 4: Distribution of the different elements between the soluble and insoluble fractions

For sake of comparison, samples collected in the road strip not yet in use (site 3) have been analyzed and results relative to both the soluble and insoluble fraction are reported in Table 6. The most abundant elements are again Al and Fe whose occurrence could be mainly ascribable to a natural origin. Meanwhile Al and Fe are preferentially associated to the insoluble fraction, Zn, Cu, Pb are more abundant in the soluble one. This different repartition between the two fractions is due to the most likely source of such contaminants in this area. The site is surrounded by cultivated fields, where the use of metal containing pesticides is a major source of heavy metals in a water soluble form. Concentration levels measured are anyway lower than those found in sites 1 and 2, even if differences with site 1 are not remarkable. Moreover, it has to be considered that samples have been collected after a dry period and therefore they are more comparable with those collected during the summer campaign.

Table 6: Metals determined in water samples collected in site 3. Concentrations expressed in $\mu g\ L^{-1}$

	Soluble fraction		Insoluble fraction	
Element	A	B	A	B
Al	82.38	172.43	1970.00	5490.00
Zn	393.00	347.00	150.00	70.00
Fe	176.40	193.90	1260.00	780.00
Cu	12.89	18.48	8.00	3.00
Pb	3.45	27.15	0.00	0.00

Soil samples were analyzed as well. Concentration levels of those element whose origin is mainly natural (Al, Fe) are at the same order of magnitude in all sites including the background one (Site 4), meanwhile Cd, Cu, and Pb are scarce in Site 4 and most abundant in Site 1 and 2, with Site 2 less polluted with respect to Site 1 (see Table 7). Such a situation reflects that occurring in particulate matter, and could also be ascribed to soil texture characteristics.

Table 7: Metals determined in soil samples. Concentrations expressed in μg Kg^{-1}

Element	Site 1	Site 2	Site 4
Al	12409.60	14881.09	12285.73
Zn	437.54	87.91	159.66
Fe	13067.05	9004.22	37422.12
Cu	50.95	9.86	1.40
Pb	66.64	101.59	46.11
Cd	4.69	4.43	1.40

PAH Analysis

PAHs were determined only in the insoluble fraction. In fact their concentration levels in the soluble fraction were always below the detection limits, i.e. 0.1 ng L^{-1}(toluene extraction-GC-MS). In order to compare the amount of eight priority PAHs present in each gram of the insoluble fraction in the two sites, concentration data, reported in Table 8, are given in ng of compound in each g of dry particulate matter. A different behaviour is observed in the two different site. In site 1, PAH concentration is much higher in Can A, as a consequence of the fact that PAHs are mainly adsorbed on the fine fraction of particulate matter that is washed out firstly. In site 2, concentration levels are similar in the two different cans; that is probably due to the fact that is such a highly industrialized area, the amount of particulate is too high to be washed out by only the first 5 litres of runoff water.

Total PAH contents (including naphthalene, phenanthrene, anthracene, and fluoranthene) in the two sites and in the two different campaigns are reported in Figure 5a. As in the metal case, a most reliable picture of the total contaminant content in the whole sample is given by Figure 5b, where PAH levels are expressed in ng L^{-1}. Also in this case, runoff waters collected after the longer dry period convey a much higher amount of pollutants with higher concentration levels measured is those samples collected in site 2.

Table 8: Priority PAH determined in each gram of particulate matter (insoluble fraction). Concentrations expressed in ng g^{-1}

Compound	Summer campaign				Autumn campaign			
	Site 1		Site 2		Site 1		Site 2	
	Can A	Can B	Can A	Can B	Can A	Can B	Can A	Can B
Pyrene	265.2	53.7	586.0	347.9	830.9	77.6	685.2	734.0
Benzo(a)anthracene	201.2	21.6	348.0	153.0	335.1	34.8	121.1	142.2
Chrysene	1242.8	108.5	318.0	669.8	1271.7	165.2	619.5	579.8
Benzo(b.j.k)fluoranthene	1132.0	95.3	1240.0	928.9	939.1	225.6	505.1	408.0
Benzo(e)pyrene	358.3	127.5	366.0	1064.8	1137.3	281.1	592.4	475.7
Benzo(a)pyrene	497.9	29.3	116.0	360. 6	317.7	71.6	166.7	142.2
Benzo(g.h.i)perylene	1112.5	116.3	138.0	1966.2	757.0	298.7	891.6	637.0
Coronene	362.8	41.4	120.0	1017.6	117.6	238.8	540.4	225.3

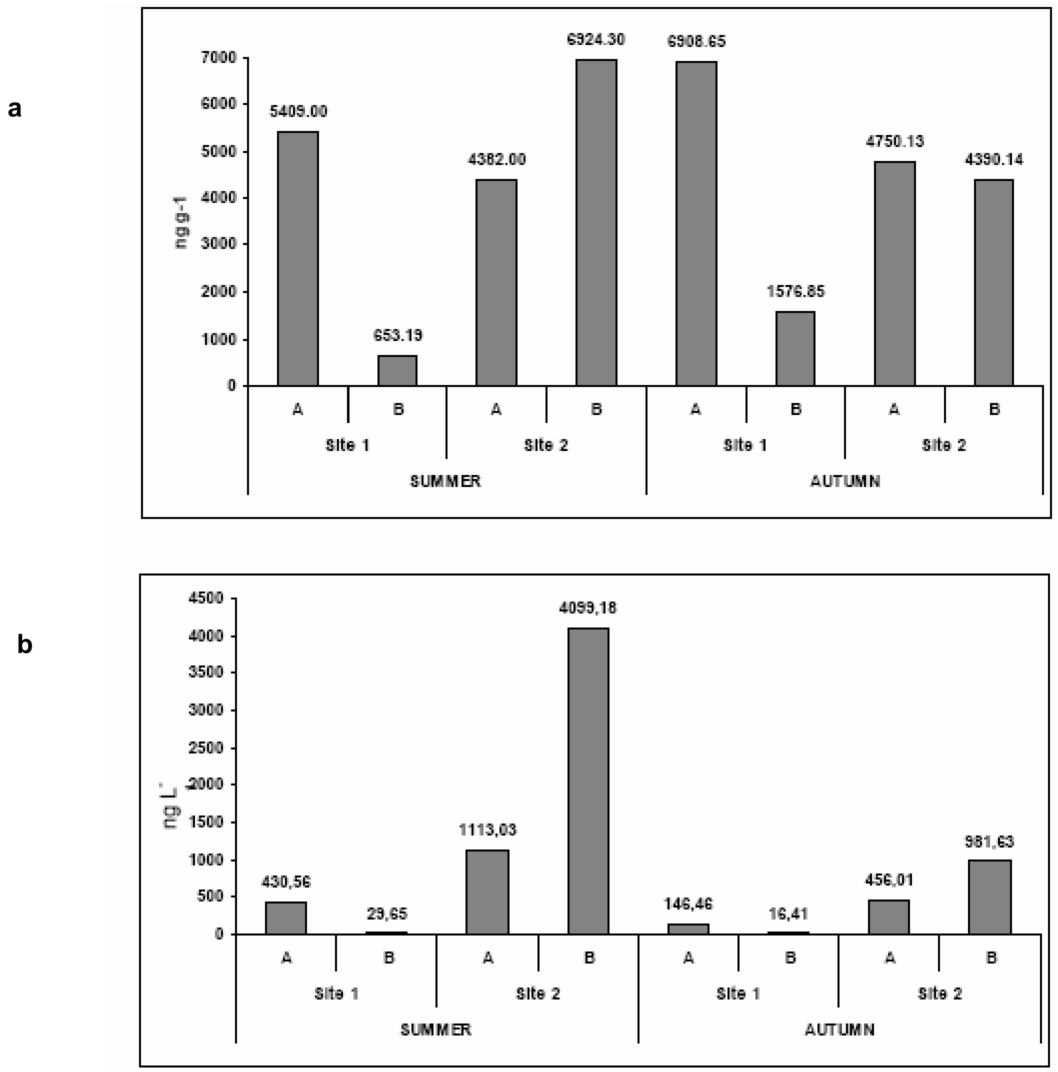

Figure 5: Total PAH contents in the insoluble fraction of samples collected in sites 1 - 2. a) Concentration expressed in ng g^{-1}; b) Concentration expressed in ng L^{-1}

PAHs were determined in site 3 as well, and results expressed in ng g^{-1} are reported in Table 9. As expected, all the compounds were present in concentration much lower with respect to the other sites. Moreover, a different pattern in the distribution of the different compounds is observed; in site 3 the prevailing species are chrysene and benzo(e)pyrene, meanwhile benzo(g, h, i)perylene, benzo(b + j + k)fluoranthene, and pyrene were the most abundant PAHs in sites 1 and 2.

PAHs present in soil samples collected in Site 1 and Site 2 showed concentration levels reflecting the same pattern as in the insoluble fraction of runoff waters, being benzo(b + j + k)fluoranthene and benzo(e)pyrene the most abundant compounds and with lower concentrations in Site 2. However, in both cases, concentrations are lower in soils with respect to particulate matter. In Site 4, PAHs were always lower than the detection limit.

Table 9: PAHs concentration levels measured in site 3. Concentrations expressed in ng g^{-1}

	Can A	Can B
Pyrene	64.6	73.7
Benzo(a)anthracene	21.1	45.9
Chrysene	147.7	311.1
Benzo(b+j+k)fluoranthene	61.0	89.0
Benzo(e)pyrene	179.8	296.3
Benzo(a)pyrene	38.7	46.1
Dibenzo(a.h)anthracene	66.4	130.4
Benzo(g.h.i)perylene	22.6	28.2
Coronene	158.2	132.1

Ion Analysis

Cations and anions were determined by Ion Chromatography in the sample soluble fraction. Results are reported in Table 10, showing that Ca^{2+} and SO_4^{2-} are by far the most abundant ions in all samples. Those ions are clearly ascribable to gypsum, whose elevated occurrence in the environment is related to a great number of natural and anthropogenic sources like fractional crystallization of marine aerosols, reaction of marine $CaCO_3$ with atmospheric sulfur components, mainly H_2SO_4, formed by the oxidation of SO_2. A variety of land-based sources of $CaSO_4$ have been suggested as well, like weathering of limestone buildings, attrition of building materials such as plaster and dusts. Also land-derived $CaCO_3$ can react with atmospheric SO_2 or H_2SO_4 to form airborne $CaSO_4$. $CaCO_3$ is present in dust from cement plants or is originating from soil dust and road wear. Lastly, another source of airborne $CaSO_4$ is the desulphurization processes in thermal power plants that use limestone for SO_2 removal (Hoornaert et al., 1996). In this study both marine and land-based sources can be hypnotized.

Table 10: Cations and anions determined by IC in the soluble fractions. Concentrations expressed in mg L^{-1}

Ions	Summer Campaign				Autumn Campaign			
	Site 1		Site 2		Site 1		Site 2	
	Can A	Can B	Can A	Can B	Can A	Can B	Can A	Can B
pH 20°C	7,1	7,8	7,5	7,5	8,0	7,9	8,1	8,0
Na^+	6,3	2,8	3,4	2,5	4,3	4,8	4,7	3,6
NH_4^+	0,4	0,3	0,7	0,5	0,4	n.d.	0,3	0,4
K^+	2,8	4,5	2,0	1,9	1,7	1,9	3,2	2,3
Mg^{2+}	1,4	0,8	1,6	1,0	1,8	1,8	2,6	2,0
Ca^{2+}	31,4	23,2	23,0	23,2	28,4	25,5	36,2	29,6
F^-	0,05	0,08	0,1	0,04	0,2	0,09	0,1	0,1
Cl^-	3,8	5,3	3,9	2,3	5,9	6,1	6,5	4,5
NO_2^-	1,8	1,2	0,4	0,3	0,2	0,3	0,8	0,8
NO_3^-	3,2	3,0	5,8	4,3	4,7	4,9	8,0	4,5
SO_4^{2-}	12,1	11,5	12,4	8,0	11,7	12,6	21,0	14,4

CONCLUSIONS

The organic and inorganic pollutant content of first flush runoff waters from an highway located in central Italy was evaluated. The sampling approach chosen was aimed at assessing the maximum pollutant load that could be delivered to the surrounding environment from a fast flowing extra-urban highway.

In order to prevent pollutants to enter aquatic systems via runoff, the construction of finished aluminium drains is foreseen. In this way first flush waters will be conveyed in suitable tanks where polluted waters could be properly treated.

Further developments of this study will be a thorough estimation of the pollutants fluxes, in order to better assess their fate in the different environmental compartments, such as soils, and surface and underground waters.

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