**1 Cocaine and other illicit drugs in airborne particulates in urban environments:
2 a reflection of social conduct and population size**

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1

2Abstract

3

4Levels of cocaine and other psychoactive substances in atmospheric particulate matter
5(PM) were determined in urban environments representing distinct social behaviours
6with regard to drug abuse: night-life, university and residential areas. Three cities (with
7population > 1 million and <0.3 million inhabitants) were selected. Mean daily levels of
8drugs in PM were 11-336 pg/m³ for cocaine, 23-34 pg/m³ for cannabinoids, and 5-90
9pg/m³ for heroin. The highest levels were recorded on weekends, with factors with
10respect to weekdays of 1-3 for cocaine, 1-2 for cannabinoids and 1.1-1.7 for heroin.
11Higher levels were detected in the night-life areas, pointing towards consumption and
12trafficking as major emission sources, and possibly ruling out drug manufacture. The
13similarities in temporal trends at all sites suggested a city-scale transport of
14psychoactive substances. Correlations were detected between cocaine and
15amphetamine consumption ($r^2=0.98$), and between heroin and cannabinoids ($r^2>0.82$).

16

17**Keywords:** cocaine, illicit drugs, PM_{2.5}, Spain.

18

19**Capsule:** The presence of illicit drugs in atmospheric particles can be used to track
20illicit drug abuse.

21

22Introduction

23Cocaine and other psychotropic substances are present in detectable amounts in
24atmospheric particulates (PM) in urban environments (Hannigan et al., 1998; Balducci
25et al 2009, Cecinato et al. 2007, 2009, 2010, Viana et al., 2010). The presence of these
26substances in the atmosphere, in the levels reported in the literature (in the order of
27pg/m³), does not pose a threat to human health given that exposures of thousands of
28years would be required to inhale the equivalent of 1 dose of drug (Viana et al., 2010).
29However, even if psychoactive effects of this exposure may be discarded, the question
30remains as to whether any health hazards may derive from the chronic exposure to
31such low ambient concentrations. In addition, the potential effects of short- or medium-
32term exposures on specific risk groups (children, elderly, asthmatics) are still unknown
33(Oliveira et al., 1997; Cecinato et al., 2010). One additional incognita is the prevalence
34of these compounds in the atmosphere, i.e., whether they remain in suspension and
35propagate unaltered after their release. Thus, monitoring of levels of cocaine and other
36drugs in ambient air should be pursued, in order to understand their behaviour,
37potential sources and effects.

1

2Currently, studies dealing with the presence of drugs of abuse in ambient air are
3relatively scarce worldwide (Hannigan et al., 1998; Balducci et al 2009, Cecinato et al.
42007, 2009, 2010, Viana et al., 2010). These studies are mostly descriptive of the
5levels of psychotropic substances in different urban, suburban and rural environments
6in Europe (Italy, Spain, Portugal, Serbia), Africa (Algeria) and South America (Chile,
7Brazil), but they rarely (Cecinato et al., 2010) focus on the distribution of the levels of
8these substances within the cities themselves. In the present work, we aim to study
9cocaine and other illicit drug contents in PM from the point of view of their potential
10emission sources. Given that consumption and small-scale trafficking of these
11substances are considered their main sources, it is our interest to study urban
12environments characterised by markedly different social conducts with respect to drug
13consumption: night-life areas, university campus, residential areas and one suburban
14area. The social behaviour with respect to drug abuse in each of these urban
15environments is clearly distinctive, and therefore the levels of illicit drugs in the air and
16their time-evolution are expected to differ. In addition, correlations between different
17drug types (suggesting different consumer groups) are also expected to be observed.
18Given that population size is a well-known modifier of social conduct and life-style, 3
19Spanish cities were the objects of study (Figure 1): Madrid (3.255.944 inhabitants,
205.335 hab/km²), Barcelona (1.621.537 inhabitants, 15.951 inhab./km²) and A Coruña
21(221.988 inhabitants, 6.680 inhab./km²) (INE, 2009). The main goal of the present work
22was to determine and interpret the levels and spatial and temporal variability of cocaine
23and selected illicit drugs in airborne particulates, as a reflection of social conduct and
24population size.

25

26**Materials and methods**

27

28Sampling of atmospheric illicit drugs

29Levels of cocaine and other psychotropic substances were determined in atmospheric
30particulate matter (PM). PM sampling was carried out at 9 locations in 3 Spanish cities:
31Barcelona, Madrid and A Coruña (Figure 1 and Table 1). Three types of urban
32environments were selected in each city: one night-life area, one residential area, and
33one university campus (in A Coruña this area was substituted by the suburban area,
34due to the fact that no appropriate location was found at the university campus).
35Sampling was carried out simultaneously at the three types of environment within each
36city, for a 7-8 day period at each site.

37

1PM sampling was performed using high-volume samplers (30 m³/h; MCV S.A in
2Barcelona and Madrid, and MCV S.A, Tisch-Graseby and Digitel DHA in A Coruña) with
315-cm diameter quartz fibre filters (Munktell) as collection substrates. The PM inlets
4used had a PM₁₀ cutoff in Barcelona and A Coruña, and a PM_{2.5} cutoff in Madrid.
5Simultaneous PM₁₀ and PM_{2.5} samples were collected in Barcelona which
6demonstrated, as will be described in the section "Grain size distribution", the
7comparability between the results from the PM₁₀ and PM_{2.5} samples (at least for
8cocaine and benzoylecgonine). Samples were collected over 24-hour periods from
9Monday to Sunday. In total, 66 valid samples were collected (21 in Barcelona, 21 in
10Madrid and 24 in A Coruña).

11

12Chemical analysis of illicit drugs in atmospheric PM

13Filters were baked during 4-6h at 200°C to eliminate organics and allow a more
14accurate weighing. All filters were then conditioned at standard temperature and
15relative humidity conditions for at least 24h before and after sampling, and then
16weighed using a Sartorius microbalance with 0.0001g precision. Prior to analysis, mass
17determination was achieved by gravimetry.

18

19In a section of ½ filter, a total of 17 illicit drugs and metabolites were investigated by
20applying an analytical methodology described by Postigo et al. (Postigo et al., 2009). In
21addition to the drugs themselves, metabolites (some of them urinary) were also
22included in the list of target analytes because they have also been identified as major
23transformation products of the drugs, formed in the environment by processes such as
24hydrolysis or photolysis, and also because they may be present in the drugs as
25impurities (El-Haj, 2004, Yoshioka and Stella, 2002). Therefore, they may be
26considered as tracers of drug consumption. Target compounds include cocaine (COC),
27its metabolite benzoylecgonine (BE), and its transesterification product cocaethylene
28(CE) that is formed when cocaine and ethanol are taken simultaneously, five
29amphetamine-like compounds (amphetamine (AM), methamphetamine (MA), 3,4-
30methylenedioxymethamphetamine (MDMA or ecstasy), (*R,R*)-(-)-pseudoephedrine (PS-
31EPH), and (1*S*,2*R*)(+)-ephedrine hydrochloride (EPH-HCl), the last two measured
32together as total ephedrine (EPH)), three opiates (morphine (MOR), heroin (HER), and
33its metabolite 6-acetylmorphine (6ACM)), three cannabinoids (Δ^9 -tetrahydrocannabinol
34(THC) and its metabolites 11-nor-9-carboxy-THC (nor-THC) and 11-hydroxy-THC (OH-
35THC)), and three lysergic acid derivatives (lysergic acid diethylamide (LSD) and its
36metabolites nor-LSD and nor-iso LSD (nor-LSD), and 2-oxo-3-hydroxy-LSD (O-H-
37LSD)). High purity (>97%) standard solutions of the target compounds and isotopically

1labelled analogues for most of them were obtained from Cerilliant (Round Rock, TX,
2U.S.A.) as solutions in methanol or acetonitrile. Deuterated compounds were used as
3surrogate standards for quantification to correct for potential analyte losses during the
4analytical process as well as for potential matrix effects. To that end, 25 ng of each
5deuterated compound were spiked to ½ filter at least 12 h prior to analysis.
6Atmospheric particles collected on the spiked quartz fibre filters were extracted by
7means of an optimized pressurized liquid extraction (PLE) protocol using methanol and
8methanol-acetone (50:50, v/v) as extraction solvents. Resulting extracts were filtered
9(0.45 µm, PTFE material), evaporated under a gentle nitrogen stream until dryness,
10and finally reconstituted with 500 µL of methanol. Only 5 µL of the final extract were
11transferred to the chromatographic system and analysed by means of liquid
12chromatography-electrospray-tandem mass spectrometry (LC-ESI-MS/MS). Mass
13acquisition was performed in the selected reaction monitoring (SRM) mode. Two SRM
14transitions were registered for each analyte, which provides four identification points,
15and hence reliability of results. This method was satisfactory in terms of sensitivity (with
16limits of determination between 0.35 pg/m³ for O-H-LSD and 22.55 pg/m³ for nor-THC),
17accuracy (with absolute recoveries percentages >50% for most compounds), and
18precision (with relative standard deviations <13% for all compounds, except for
19cannabinoids). The analysis of laboratory blanks, handled and analysed in the same
20way as the samples, evidenced no background contamination by the target analytes.
21Further details of the optimization and validation of the analytical method are described
22in Postigo et al. 2009.

23

24Results and discussion

25

26Grain size distribution

27Because of the different inlets used in Madrid (PM_{2.5}) with respect to Barcelona and A
28Coruña (PM₁₀), resulting from instrument availability during sampling, three
29simultaneous PM₁₀ and PM_{2.5} samples were collected in the Barcelona university area
30(Table 2). Results were above the detection limit only for cocaine (COC) and its
31metabolite benzoylecgonine (BE) during these days. COC and BE levels were similar
32in PM_{2.5} than in PM₁₀, and the differences between the levels in both size fractions were
33always at least one order of magnitude lower than the standard deviation for the entire
34dataset (Table 3). Thus, these results suggest that the aerodynamic diameter of
35cocaine and benzoylecgonine is <2.5 microns, and that the differences obtained
36between PM_{2.5} and PM₁₀ result from analytical uncertainty. Thus, the results from the
37PM₁₀ and PM_{2.5} size fractions are considered comparable. The somewhat larger

1 difference obtained for cocaine on 09/11/2008 (Table 2) is ascribed to the analytical
2 process, due to the fact that this difference is not observed for BE which is a metabolite
3 of COC and which should thus follow a similar trend.

4

5 Levels and spatial and temporal variability of drugs in PM

6

7 The mean daily concentrations of the illicit drugs and metabolites analysed are
8 summarised in Table 3 and Figure 2. The following discussion on the levels and spatial
9 and temporal variability will focus mostly on cocaine given that it is the only compound
10 for which the levels obtained were significantly above the detection limit for all samples.
11 Heroin and cannabinoids (THC) were detected on a smaller sub-set of samples (31
12 and 19 samples, respectively, out of 66) and will also be discussed even if in less
13 detail. Finally, ephedrine, amphetamine, methamphetamine and ecstasy (MDMA) were
14 only detected in a maximum of 6 samples (per compound) and therefore no conclusive
15 trends could be extracted. The levels of nor-THC, OH-THC, nor-LSD and O-H-LSD
16 were below detection limit and are not shown in the text. Regarding meteorological
17 conditions during the sampling period, they may be considered similar at all sites:
18 atmospheric transport scenarios were dominated by anticyclonic conditions during the
19 sampling weeks in Barcelona, Madrid and A Coruña, with low wind speeds and in the
20 absence of precipitation (with the exception of A Coruña during the first 2 sampling
21 days). In Madrid, strong winds were detected during two of the sampling weekends
22 (see description below).

23

24 On average, daily mean cocaine levels ranged between 11 and 336 pg/m³ at all sites
25 (Figure 2a). These levels are of the same order of magnitude as those described for
26 Madrid and Barcelona (204–480 pg/m³, Viana et al., 2010) and Italy and Portugal (13-
27 267 pg/m³ and 148 pg/m³, Cecinato et al., 2009). Levels of heroin ranged between 5
28 and 90 pg/m³, and those of cannabinoids (THC) between 23 and 34 pg/m³ (Figures 2b
29 and 2c). Heroin levels were thus also similar to those previously reported for Madrid (9-
30 143 pg/m³, Viana et al., 2010), while THC levels were markedly lower than those
31 reported for Madrid and Barcelona (3-110 and 3-156 pg/m³, respectively, Viana et al.,
32 2010). Regarding the levels of metabolites, BE and 6ACM showed strong correlations
33 with their parent compounds (COC and HER, respectively) on a daily basis: the
34 correlation between COC and BE was $r^2=0.77$ ($r^2=0.86$ excluding one outlier, for 23
35 pairs of data available), and between HER and 6ACM it was $r^2=0.77$ (no outliers, 6
36 pairs of data available). Thus, the variability on the levels of metabolites BE and ACM
37 confirmed the analytical procedures and the interpretations of the temporal trends of

1their parent drugs (COC and HER), provided below, as tracers of drug consumption.
2Finally, levels of ephedrine were only detected in Barcelona and on average they
3ranged between 3.1 pg/m³ in the night-life area and 4.3-4.4 pg/m³ in the university and
4residential areas.

5

6As a function of the city of study, no consistent differences were obtained between the
7levels of the different drugs, i.e., levels of all substances were not consistently higher or
8lower in a given city. As shown in Figure 2, mean daily levels of cocaine were similar in
9Barcelona and Madrid (although slightly higher in Barcelona), and higher than in A
10Coruña. Conversely, the levels of heroin were higher in A Coruña, where it was
11detected at all sites, while in Madrid and Barcelona this substance was only detected at
123 out of the 6 study locations (and in lower concentrations). Finally, the levels of
13cannabinoids ranged rather evenly between 23 and 34 pg/m³ in the three cities. As a
14result, cocaine levels could be linked to population size (not population density),
15whereas the levels of heroin and cannabinoids in the three cities seemed to be
16independent of it. There might exist, in addition, a certain link between cocaine levels
17and acquisition power, given that the price of cocaine (with higher levels in the larger
18cities) is much higher (14.1 €/dose) than that of cannabis (3.0 €/g of marihuana, with an
19approximate 1.5 g/dose, OED, 2007). However, more data would be necessary to
20confirm this hypothesis. It is important to consider that, currently, cocaine and cannabis
21are perceived as recreational drugs whereas heroin abuse is a more marginal conduct.

22

23Conversely, the results evidence that the levels of illicit drugs in ambient air are a good
24indicator of social behaviour with respect to drugs of abuse (consumption and/or small-
25scale trafficking). As shown in Figure 2 (with the only exception of the Barcelona
26residential area, discussed below), there is a clear decreasing trend in the levels of
27cocaine, heroin and cannabinoids from the night-life areas, to the university campus
28and the residential areas. This trend was detected at 8 out of 9 study sites, with ratios
29for cocaine between the night-life and the residential areas of 7-12, and between the
30night-life areas and universities ranging between 2 and 5. Therefore, our results reflect
31the larger consumption and/or trafficking of cocaine, heroin and cannabinoids known to
32take place in night-life areas, with levels up to 12 times higher than in the residential
33areas. As for the university areas, it is somewhat surprising to observe the low factor
34obtained in Barcelona, indicating that the difference between the ambient air levels of
35cocaine are only different in the night-life area from the university by a factor of 2. This
36factor was even lower (1.5) when comparing cocaine levels in the night-life and the

1suburban areas in A Coruña, but the absolute levels were lower (maximum of 85 pg/m³,
2as opposed to 336 pg/m³ in Barcelona).

3

4The only exception to the decreasing trend observed from the night-life to the
5residential areas were the high cocaine levels detected at the Barcelona residential
6area (336 pg/m³), which were markedly higher than those measured in the night-life
7area (193 pg/m³). Additionally, a strong correlation was found between cocaine and
8amphetamine at this site (as will be shown in the section “Consumption patterns”), and
9previous results (OED, 2007; Viana et al., 2010) demonstrate a link between cocaine
10and amphetamine use within the same consumer group. Therefore, it is possible to
11conclude that drug abuse or trafficking may take place at this location, despite its
12residential character. Consequently, the analysis of illicit drugs in ambient particulates
13may be considered a useful tool to monitor illicit drug abuse or trafficking in urban
14environments, and to detect it even in areas where it might not be expected.

15

16The daily variability of the levels of cocaine, heroin, cannabinoids and ephedrine was
17also analysed, as a function of weekdays (Monday to Thursday) vs. weekends (Friday
18to Sunday, Figure 3). One issue which remains unclear in the literature is if the
19occurrence of illicit drugs in the atmosphere is related to trafficking, manufacture or
20abuse (Cecinato et al., 2010). Based on our results, it would seem that illegal trade and
21consumption of these substances are the main emission sources, given that a strong
22trend with maximum levels on weekends was detected. This would possibly rule out
23manufacture as a major emission source, given that either constant emissions
24throughout the week or higher weekday levels would be expected from this source.
25There seems to be no reason to justify higher manufacture during week ends. Instead,
26our results evidenced higher levels of all substances (cocaine, heroin, cannabinoids
27and ephedrine) on weekends at all types of sites (with the only exception of the Madrid
28night-life site for heroin and THC). This result was expected in the night-life areas, due
29to the increased consumption or trafficking. However, it is interesting to observe that
30the same trend is detectable at the university and residential areas, where either: (a)
31levels were expected to be higher on weekdays due to the presence of students
32(university), or (b) levels were expected to remain constant due to the absence of
33consumption (residential area). Conversely, higher levels were always detected during
34weekends. This result suggests a long residence time of these substances in the
35atmosphere, which seem to remain in suspension and propagate unaltered after their
36release. Thus, we may hypothesize that drug emissions into the atmosphere take place
37mostly in the night-life areas and on weekends, and that drugs are then transported on

1the city-scale and detected in residential and university areas. Because of dilution
2processes during transport of the drugs, it is not possible with the current data to
3quantitatively estimate the atmospheric residence time of the drugs analysed.

4

5The trends obtained for cannabinoids and heroin in Madrid were an exception and did
6not follow the above described trend (Figure 3). Partly, the higher weekday levels may
7be interpreted as a result of the influence of meteorology, given that the weekend days
8coincided with winds which markedly reduced PM_{2.5} levels (12 µg/m³ on weekends as
9opposed to 23 µg/m³ on weekdays). This reduction in PM_{2.5} levels would inevitably
10decrease the levels of illicit drugs in the atmosphere. However, this weekend decrease
11was not observed for cocaine. One additional explanation may be that the higher
12weekday levels detected for heroin and cannabinoids are not an artefact, and that they
13reflect an actual consumption pattern. This would be supported by the high correlation
14obtained between both substances ($r^2 = 0.82$, Table 4, described in the section
15“Consumption patterns”). However, the weekday maximum for cannabinoids and heroin
16is only observed in Madrid (and not in Barcelona or A Coruña), and even though it is
17possible, it is unlikely that there exists a specific consumption pattern in Madrid which
18is different to other cities. Finally, the atmospheric reactivity of the drugs may also exert
19an influence on their prevalence in the atmosphere, and therefore on the temporal
20trends (Cecinato et al., 2010). In sum, the cause of the temporal trend observed is still
21unclear.

22

23Consumption patterns

24

25Correlation analyses were carried out between the levels of the different substances in
26the three cities (Table 4). The aim of this analysis was to detect correlations which may
27be interpreted as characteristic consumption patterns. Results showed that a high
28correlation ($r^2 = 0.98$) was obtained between amphetamine and cocaine (enough data >
29DL only available in Barcelona), suggesting that the consumption of these two
30substances coincides in time, either by the same or different consumers. This confirms
31the findings from our previous study (Viana et al., 2010). In addition, strong correlations
32were observed between cannabinoids and heroin in Madrid and Barcelona ($r^2 = 0.82$ and
331.00, respectively), whereas the correlation was only moderate in A Coruña ($r^2 = 0.59$).
34Once again, results would suggest a link between the consumption of cannabinoids
35and heroin in the larger cities. Conversely, low correlation factors were obtained
36between cocaine and heroin in Barcelona and Madrid ($r^2 = 0.27$ and 0.26, respectively),
37which were moderate in A Coruña ($r^2 = 0.64$). The consumption of heroin and cocaine

1 was not expected to be linked in space and time, given the different profiles of
2 consumers of both substances (UNODC, 2008). Based on these results, population
3 size (but not population density) seems to exert an influence on drug consumption
4 patterns, given that differences were detected between the larger (Barcelona and
5 Madrid) and smaller (A Coruña) urban environments. When assessing the ratios
6 between the levels of different substances (e.g., the ratio cocaine-to-heroin,
7 COC/HER), similar values were obtained for Madrid and Barcelona (7.6 and 7.4,
8 respectively) which differed largely from those obtained in A Coruña (COC/HER=1.0).

9

10 In addition, the ratios between weekend and weekday levels for the different
11 substances (Figure 3) also revealed characteristic consumption patterns: cocaine
12 levels were higher on weekends than on weekdays by a factor of 1 to 3, cannabinoids
13 were higher by a factor of 1 to 2, and heroin was higher by a factor of only 1.1 to 1.7.
14 As described above, cocaine and cannabis are perceived as recreational drugs
15 whereas heroin abuse is a more marginal conduct, and therefore cocaine and
16 cannabinoid levels show a much stronger increase during weekends than those of
17 heroin. Conversely, heroin consumption is relatively more constant throughout the
18 week, according to airborne concentrations of these substances.

19

20 **Conclusions**

21

22 The levels and temporal variability of cocaine and other psychoactive substances was
23 studied in three environments characteristic of different social conducts with respect to
24 illicit drug abuse: night-life, university and residential areas. Provided that population
25 size is a well-known modifier of social conduct and life-style, 3 Spanish cities were the
26 objects of study: Madrid, Barcelona and A Coruña. On average, daily concentrations of
27 illicit drugs in airborne particulates ranged between 11-336 pg/m³ for cocaine, 23-34
28 pg/m³ for cannabinoids, and 5-90 pg/m³ for heroin. These concentrations do not pose a
29 threat to human health according to current literature, but based on our results they
30 may be considered valid indicators of social conduct with respect to illicit drug
31 consumption. Higher levels of all substances were generally found on weekends with
32 respect to weekdays (by factors of 1 to 3 for cocaine, factors of 1 to 2 for cannabinoids,
33 and factors of 1.1 to 1.7 for heroin), suggesting that the major emission sources of
34 these substances in the air are drug consumption and/or trafficking. Manufacture, on
35 the other hand, does not seem to constitute a significant emission source. Given that
36 the same temporal trend was found in night-life areas (with highest emissions) as in
37 university and residential areas, it was concluded that cocaine and other drugs prevail

1in the atmosphere after emission and are transported unaltered across urban
2environments. However, atmospheric conditions (meteorology) can strongly affect the
3dilution rates and the transport patterns at local level, while the drug reactivity may
4affect their persistence in the atmosphere. Consumer patterns were identified based on
5the correlation between the airborne levels of the different substances: cocaine and
6amphetamine consumption appeared to be linked in Barcelona ($r^2=0.98$), and the same
7was observed for cannabinoids and heroin in the larger cities ($r^2>0.82$, not in A
8Coruña). Finally, the highest levels of cocaine were unexpectedly detected at the
9residential area in Barcelona. This result evidenced that the analysis of illicit drugs in
10atmospheric particulates may be considered a useful tool to monitor illicit drug abuse or
11trafficking in urban environments, enabling the detection of drug emissions even in
12areas where it might not be expected.

13

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15

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1Figure captions

2

3Figure 1. Location of study cities.

4Figure 2. Levels (pg/m^3) of cocaine, heroin and cannabinoids in the night-life,
5university/suburban and residential areas in Barcelona, Madrid and A Coruña. The
6mean HER value detected in the residential area in COR is below the average method
7limit of determination, but above the limit of determination observed in that sample.

8Figure 3. Weekend and weekday levels (pg/m^3) of cocaine, heroin, cannabinoids and
9ephedrine in Barcelona, Madrid and A Coruña.

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11

12Tables

13

14Table 1. Description of sampling sites and dates.

City	Area	Location	PM fraction
Madrid (27/11-14/12/2008)	Night-life	Malasaña	PM _{2.5}
	University	Complutense University	PM _{2.5}
	Residential	Aravaca	PM _{2.5}
Barcelona (08/11-14/11/2008)	Night-life	Pl. Gala Placidia	PM ₁₀
	University	Polytechnical University	PM ₁₀
	Residential	Av. Roma	PM ₁₀
A Coruña (11/02-18/02/2009)	Night-life	Orzán	PM ₁₀
	Suburban	San Diego	PM ₁₀
	Residential	Liáns	PM ₁₀

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16

17Table 2. Comparison between mean daily levels (pg/m^3) of cocaine (COC) and
18benzoylecgonine (BE) in PM₁₀ and PM_{2.5} samples collected simultaneously at the
19university area in Barcelona.

Date	08/11/2008		09/11/2008		12/11/2008	
	PM _{2.5}	PM ₁₀	PM _{2.5}	PM ₁₀	PM _{2.5}	PM ₁₀
COC (pg/m^3)	170	166	254	206	45	40
BE (pg/m^3)	35	31	37	35	6	7

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21

Table 3. Mean daily levels and standard deviation (SD) of PM ($\mu\text{g}/\text{m}^3$) and drugs of abuse (pg/m^3) in Barcelona (BCN), Madrid (MAD) and A Coruña (COR) at the residential, university/suburban and night-life areas. * PM₁₀ in Barcelona, PM_{2.5} in Madrid and PM₁₀ in A Coruña. ** Only one sample >DL. The levels of cocaine, heroin and cannabinoids are shown in Figures 2a-2c. Values in brackets below the target analytes indicate the corresponding method limits of determination (LODet) in pg/m^3 (see Postigo et al., 2009 for details on their calculation). LODet values were 3.10 pg/m^3 for COC, 9.03 pg/m^3 for HER, and 5.23 pg/m^3 for THC (levels shown in Figures 2a-c).

	pg/m^3	Night-life		University/Suburban		Residential	
		Mean	SD	Mean	SD	Mean	SD
PM* (1.5)	BCN	32	5	32	7	37	5
	MAD	19	11	15	8	12	7
	COR	43	15	36	6	24	4
AM (1.05)	BCN	13	0.5	<DL	<DL	15	**
	MAD	<DL	<DL	<DL	<DL	<DL	<DL
	COR	<DL	<DL	<DL	<DL	<DL	<DL
MDMA (1.26)	BCN	<DL	<DL	<DL	<DL	<DL	<DL
	MAD	3.0	**	<DL	<DL	<DL	<DL
	COR	5.0	**	<DL	<DL	<DL	<DL
EPH (1.73)	BCN	3.1	**	4.4	**	4.3	1.5
	MAD	<DL	<DL	<DL	<DL	<DL	<DL
	COR	<DL	<DL	<DL	<DL	<DL	<DL
BE (2.49)	BCN	29	19	19	11	54	52
	MAD	15	9	<DL	<DL	7	<DL
	COR	8	5	3	**	<DL	<DL
MA (2.73)	BCN	6	<DL	<DL	<DL	2.8	<DL
	MAD	10	10	<DL	<DL	<DL	<DL
	COR	<DL	<DL	<DL	<DL	<DL	<DL
6ACM (7.36)	BCN	32	**	<DL	<DL	18	7
	MAD	10	3	<DL	<DL	<DL	<DL
	COR	28	11	9	5	<DL	<DL

9AM: amphetamine. MDMA: ecstasy. EPH: ephedrine. BE: benzoylecgonine (cocaine metabolite). MA: metamphetamine. 6ACM: 6-acetylmorphine (heroin metabolite).

11 *PM₁₀ in Barcelona, PM_{2.5} in Madrid and PM₁₀ in A Coruña.

12** Only one sample > LODet. <DL: below method limit of detection

13

14Table 4. Correlation between different substances (AM, amphetamine; COC, cocaine; 15THC, cannabinoids; HER, heroin) in airborne particulates. * AM vs COC could not be 16calculated for Madrid and A Coruña, since AM levels were below the method limit of 17detection in all analysed samples.

R ²	Barcelona	Madrid	A Coruña
AM vs. COC*	0.98	-	-
THC vs. HER	1.00	0.82	0.59
COC vs. HER	0.27	0.26	0.64

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