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Cocaine and cannabinoids in the atmosphere of Northern Europe cities, comparison with Southern Europe and wastewater analysis

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ABSTRACT

This study reports the first investigation of atmospheric illicit drug concentrations in Northern Europe using measurements of cocaine and cannabinoids in Amsterdam, London and Stockholm. Further, these measurements were compared to those made in Rome to explore the geographical and inter-city variability. Co-located measurements of atmospheric particulate mass and PAHs were used to help describe and interpret the illicit drug measurements with respect to atmospheric dispersion. Cocaine concentrations ranged from 0.03 to 0.14 ng/m^3 in Amsterdam, from 0.02 to 0.33 ng/m^3 in London and were below quantification limit (3 pg/m^3) in Stockholm. Cannabinol was the only cannabinoid molecule detected in the three cities. During this campaign, London reported the highest concentrations of cocaine and meaningful differences were detected between the urban background and city centre London sites. Mean cocaine concentrations measured in Amsterdam during March 2011 were also compared with those measured simultaneously in eight Italian cities. The cocaine concentration in Amsterdam was comparable to that measured at an urban background in Milan and at a densely populated site in Florence. Although correlating atmospheric concentrations directly with drug prevalence is not possible using current data, links between concentrations of cocaine and estimates of abuse prevalence assessed by the more routinely used wastewater analysis were also examined. A statistically significant correlation was found between the two sets of data ($R^2 = 0.66$; $p = 0.00131$). Results confirmed that meteorology, population rate and habits of consumption influence the atmospheric concentrations of drugs. If these confounding factors were better controlled for, the techniques described here could became an easy and cost effective tool to index the impact of cocaine abuse in the area; especially where local hot spots need to be identified.

1. Introduction

In recent years, environmental research has gained an increasing interest in new classes of compounds, comprising illicit psychotropic substances (PS). Although the potency of the biological effects of illicit drugs is recognized, very little is known about their potential harmful impact on the environment (Daughton, 2011). Most investigations have focused on developing tools to evaluate the abuse prevalence by measuring levels of drug residuals in wastewater (Zuccato et al., 2005; Thomas et al., 2012; Mastroianni et al., 2013; Ort et al., 2014; Castiglioni et al., 2014). Traces of illicit substances have also been found worldwide in surface and drinking waters (Seabra Pereira et al., 2016; van der Aa et al., 2013; Huerta-Fontela et al., 2008) and in sediments and sludges (Álvarez-Ruiz et al., 2015). In this context the ambient atmospheric concentrations have been less well studied despite evidence of cocaine presence in the atmospheric particulate being reported since 1998 (Hannigan et al., 1998). Acute health risk associated with exposure to typical ambient concentrations of illicit drugs has been regarded as negligible (Viana et al., 2010). Nonetheless, the occurrence of illicit drugs in the air merits concern, taking into account that the atmosphere is a key pathway of dispersion both at local and global scale, and the risks posed by chronic exposure to these substances are completely unknown (Mastroianni et al., 2015). This issue is even more important when considering that dedicated investigations have reported that indoor air (houses, offices, primary schools and shops) can be more contaminated by illicit drugs than ambient air (Cecinato et al., 2014, 2016; Bianchi et al., 2014) even where drugs are not consumed. To date little information exists at this regard (McKenzie et al., 2013), but this phenomenon is expected to be

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accentuated at locations close to drug abuse or manufacture. In fact, cases of positive response to bioassays have been reported both in children and adults even in the absence of direct drug consumption (Kidwell et al., 1997; De Giorgio et al., 2004; Garcia-Bournissen et al., 2009; Pichini et al., 2014). In ambient air the highest concentrations of these substances have been reported from spot measurements carried out in Latin America. Cocaine concentrations as high as 17 ng/m^3 were found in Mexico City, and 3.3 ng/m^3 in Santiago De Chile (Cecinato et al., 2016). Cocaine was not found in Algeria, both in Algiers and surrounding areas (Ladji et al., 2009; Moussaoui et al., 2013), while traces of cannabinoids were detected. In Europe, some measurements have been made in Oporto, Portugal, and Pančevo, Serbia, but most have been made in Italy and Spain (Cecinato et al., 2009, 2010, 2012; Postigo et al., 2009; Viana et al., 2010, 2011; Mastroianni et al., 2015). In Italy, a number of localities have been investigated for cocaine and three important cannabinoids, i.e. Δ^9-tetrahydrocannabinol (THC), cannabinol (CBL) and cannabidiol (CBD) (Balducci et al., 2009). In Spain, only three cities have been investigated, but a wider range of substances were studied, including native species, by-products and metabolites (e.g., amphetamines, heroin, cocaethylene, ecstasy, benzoylecgonine, 6-acetylmorphine). This study reports the first atmospheric measurements of cocaine and cannabinoids carried out in London, Stockholm and Amsterdam.

Wide differences in meteorological and social contexts, as well as in the drug abuse prevalence, characterize the northern European cities studied; differences also exist between them and the southern European cities so far investigated. From this perspective, the first aim of this study is to provide new information on the variability of the ambient concentration of illicit drugs which reflect the differences between these cities. The second aim is to investigate the possible associations between the atmospheric concentrations and the abuse rate in the area detected there.

The concentration of illicit drugs in the atmosphere is controlled by meteorological dispersion, and little is known about drug suspension and transport from sources to the measurement locations. Using ambient concentration measurements of illicit drugs for consumption estimates is therefore unreliable using the current, limited datasets and significant challenges exist to control for variability in atmospheric dispersion. Nonetheless, studies conducted so far provide evidence that this approach can capture differences among geographical localities, locations or zones within a given area, as well as time variations from a few days to consecutive years (Cecinato et al., 2014). Therefore, measuring illicit drug concentrations in the air could potentially be applied as a new tool to identify local hot spots, which can be associated with consumption, trafficking and manufacture of substances. Recent studies suggest cocaine may be feasible for this purpose. In fact, cocaine is overall associated to the particulate phase (Cecinato and Balducci, 2007) and its determination in the PM accounts for total amount in the air. Although no specific studies have been carried out to assess the stability of illicit drugs in the atmosphere, the relative stability of cocaine seems to be inferred by its seasonal behaviour, which looks analogous to that of the PM (Perrino et al., 2001; Hu et al., 2011; Kelly et al., 2016), and the winter/summer concentration ratios for cocaine and $PM_{2.5}$ were broadly similar. For instance, in Rome, taking in account 11 sites, ratios as high as 2.1 $\pm$ 1.2 and 2.5 $\pm$ 0.9, respectively, were observed for cocaine and $PM_{2.5}$. On the contrary cannabinoids (the other extensively investigated class) have been shown to be markedly less stable showing a reduction of concentration (Cecinato et al., 2012, 2014).

The determination of cocaine and cannabinoids in the atmosphere of Northern Europe cities allowed us to further investigate links between ambient concentration and the drug addiction phenomenon. Accepting that the current knowledge is not advanced enough to quantify usage rates using ambient samples, these measurements may allow an indexing system of illicit drug prevalence to be developed using the existing sampling infrastructure available in all cities. To investigate this, atmospheric illicit drug concentrations were compared between London, Amsterdam and Rome in March 2013 as well as concentrations measured in Amsterdam and eight Italian cities in 2011. This allowed the influence of meteorology and population habits on the illicit drug concentrations to be examined.

The psychotropic compounds nicotine (NIC) and caffeine (CAF) (reported in the text as licit drugs) and polycyclic aromatic hydrocarbons (PAH) were monitored in addition, to provide insights into the characteristics of the sites and eventual peculiarities in the behaviour of illicit drugs (cocaine and cannabinoids). The improvement of the existing illicit drug concentration database, obtained through this study, allowed an examination of the concentrations of atmospheric cocaine over Northern and Southern Europe cities in the light of the drug prevalence in the respective countries. Measurements were also compared to estimates of collective consumption obtained through analysis of drug residuals in wastewater. The effectiveness of this methodology in assessing drug abuse prevalence is ascertained, and the comparison between the outcomes of the two types of study provides important information to verify if the illicit drugs impact over a certain area can be indexed through measurements in the air.

2. Experimental

2.1. Sites and periods of sampling

In Amsterdam, two series of measurements were performed from 9 to 16 March 2011 and from 7 to 27 March 2013. Three monitoring locations were investigated in the first campaign: A-BG1, urban background, A-SM1, and A-SM2, all belonging to the Amsterdam Public Health Service (GGD), Dept. of Air Quality Monitoring Network. A-BG1 was located along the perimeter of an important city park, while A-SM1 and A-SM2

Table 1
Population rate and density of the cities investigated. PM fraction sampled, sampling dates and typology of the monitoring sites in each city.

City	Population	Population density	Site symbols	Site type	PM fraction	Sampling period
Amsterdam	820,000	4892	A-BG1	BG	10–2.5	9–16/03/2011
			A-SM1	SM	2.5	7–27/03/2013
			A-SM2	SM	10	
			A-BG2	BG	10	23–24/03/2013
London	8,538,689	5432	L-BG	BG	10	7–27/03/2013
			L-KS	KS	10	10–22/07/2014
Stockholm	912,000	4872	S-BG	BG	10–2.5	18/09–15/10/2014
						30/10–12/11/2014
Rome	2,761,477	2231	Francia (FR)	SM	10	7–27/03/2013
			Belloni (BE)	BG	10	
			Cipro (CI)	BG	10	
			Villa Ada (VA)	BG	10	

Symbols adopted for sites: BG = urban background; KS = kerbside; SM = street monitoring.

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