Technical Note

Illicit Drug Contamination of the Bristol Pound Local Currency

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Abstract

Reports have shown the prevalence of the contamination of banknotes with a number of different drugs. These studies have focused on investigating drug contamination levels on currency which is either nationally or even international distributed. To present there has been no studies undertaken on banknotes circulating in well-defined and limited geographic areas. In this present study we have investigated the presence of drug contamination on the Local Currency, circulating in a known geographic area in and around the city of Bristol, UK; the Bristol Pound (£B). The effect of sample size was investigated and a post-hoc statistical power analysis undertaken. Following liquid extraction with the aid of sonication, levels of cocaine, benzoylecgonine, MDMA, ketamine and methamphetamine were determined by liquid chromatography triple quadrupole mass spectrometry. Seven samples of each denomination in circulation were investigated. The calculated median values per note were 2030 ng cocaine, 91.9 ng benzoylecgonine, 0.779 ng methamphetamine, 62.8 ng MDMA and 3440 ng ketamine. This study focuses on our preliminary studies and to our knowledge this is the first investigation focused on the drug contamination of a Local Currency.

Keywords: Drugs, Local Currency, LC–MS/MS, paper currency, Bristol Pound.

Introduction

A high percentage of circulating banknotes have been shown to be contaminated with illicit drugs [1]. This contamination is believed to result from drug dealing or drug usage [2] leading to the initial contamination of a small number of notes. This initial contamination can then be spread either by direct contact or by subsequently contaminated currency-counting machines or Automated Teller Machines (cash points) [3,4]. It is also suggested that the hygroscopic nature of many drugs can lead to deliquescence and absorption to the banknote in warm, moist environments [5], such as in pockets and wallets. Paper based banknotes are also believed to present a suitable matrix for the inclusion of drug particles [6]. Knowledge of the drugs and the amounts present on banknotes can provide important information [7]. Elevated levels above commonly recorded background levels can be used to determine drug usage and dealing [8]. The types and variety of drugs found can also give insights into changes in drug usage.

The European Drug Report published in 2019 [9] show that the availability of illicit drugs is governed by the geographic location of ports of entry, related trafficking routes, production centres and consumer markets. Cocaine is the most frequently seized stimulant in western and southern European countries, whereas, amphetamines and MDMA predominates across northern and eastern Europe. This an interesting point, as if this is correct, then it should be possible to detect some geographical or regional variation in the drugs found on different banknotes. Nevertheless, reports [4,10] have argued that there is no geographic regional variation in the quantities of drugs found. However, these studies have been undertaken on notes available in wide geographical areas, such as whole political regions and countries, not on specific geographic areas [1-8,11-22]; using currencies available throughout a much larger areas, diluting the geographic significance.

To present there have been no investigations regrading drugs contamination of Local Currencies. These can be defined as a currency that can be spent in a defined geographic area in participating shops and organisations. It is generally exchangeable on a one-to-one basis with the national currency and not designed as a replacement. It is aimed to encourage spending and its related benefits to be kept within the local community [23]. United Kingdom (UK) cities such as; Bristol and the towns of Lewes and Kingston have their own local currencies, along with areas as diverse as Brixton, the Lake District and the Findhorn Ecovillage. This aim of keeping usage within a local area or community presents an interesting aspect, as these banknotes circulate in a relatively small, well-defined area. In this present study we have focused on determining levels of drug contamination on the Local Currency, the Bristol Pound (£B). We believe that this approach would give more specific information of drug usage in a specific geographical region. We have developed a LC/MS/MS based assay to determine cocaine, benzoylecgonine, 3,4-methylenedioxymethamphetamine (MDMA), ketamine and methamphetamine contamination of the £B banknotes. This is the first study of this type to be made on a Local Currency.

2. Experimental

2.1 Chemicals and Reagents

All chemicals and reagents were purchased for Fisher Scientific unless otherwise stated. Drugs standards: 20 µg/L mixed drug standard solution (cocaine, cocaine–D_3, benzoylecgonine, benzoylecgonine D_3, ketamine HCl, Ketamine D_4 (HCl), methamphetamine, methamphetamine D_{14}); were purchased from Sigma Aldrich, Poole, UK. Water, formic acid and methanol were all LC/MS grade.

Liquid Chromatographic conditions

Chromatographic equipment consisted of an Agilent Tech 1260 infinity liquid chromatograph coupled to an Agilent Tech 6460 triple quadrupole mass spectrometer. Separations were carried out using an Agilent Poroshell 120 reversed-phase C18- column (2.7 µm particle size, 100 mm × 3.0 mm i.d.) maintained at 30 °C. The mobile phase consisted of A, 0.1 % formic acid in water, and B, acetonitrile at a flow rate of 0.4 mL/minutes. The initial conditions were 80 % A 20 % B. At injection, B was increased from 20 % B to 80 % and held at 80 % until 1.50 minutes; at 1.51 minutes, B was decreased to 20 %. The injection volume was 5 µL.

Triple Quadrupole MS conditions

The ion mode was ESI + Agilent Jet Stream. Gas temperature was set to 300 °C, gas flow was 5 L/min, and capillary voltage was 3500 V. The cell accelerator voltage (V) was 4 V. Table 1 gives an overall summary of the LC/MS/MS conditions used.

Analyte	Retention Time (min)	Precursor Ion (m/z)	Product Ion (m/z)	Dwell (ms)	Fragmentation (V)	Collision Energy (V)
Cocaine D3	3.442	307.2	85.2	50	99	36
		307.2	77.1	50	99	72
Cocaine	3.444	304.2	82.2	50	113	32
		304.2	77.1	50	113	72
benzoylecgonine D3	2.557	293.2	105.1	50	124	36
		293.2	77.1	50	124	72
benzoylecgonine	2.581	290.1	168.1	50	110	20
		290.1	77.1	50	110	64
Ketamine D4 (HCl)	2.416	242.1	224	50	88	13
		242.1	129	50	88	29
Ketamine (HCl)	2.438	238.1	220	50	106	13
		238.1	124.9	50	106	29
Methylenedioxymethamphetamine (MDMA)	2.317	194.1	163.1	50	80	8
		194.1	105.1	50	80	24
Methamphetamine D14	2.020	164.2	98.1	50	87	20
		164.2	70.2	50	87	52
Methamphetamine	2.061	150.1	91.1	50	82	16
		150.1	65.1	50	82	48

Table 1. Analytical and detection conditions of target drugs and deuterated internal standards.

Calibration

A seven-point calibration curve was constructed using concentrations 1.0 µg/L, 5.0 µg/L, 10 µg/L, 50 µg/L, 100 µg/L, 500 µg/L and 1000 µg/L was conducted for all five drugs under investigation. Each standard was run in triple. Typical chromatograms obtained for the target analyte and their deuterated standards are shown in supplementary material figure S1. Table 2 describes the analytical performance characteristics for the method for the drugs investigated.

Analyte	LOQ (ng/mL)	Upper limit of linearity (ng/mL)	Regression Equation	r^2	Significance
methamphetamine	1	1000	y=0.247x	0.999	$4.68x10^{-10}$
MDMA	1	1000	y=0.112x	0.999	$2.37x10^{-13}$
Ketamine	1	1000	y=0.203x	0.999	$1.78x10^{-10}$
benzoylecgonine	1	1000	y=0.0641x	0.999	$9.43x10^{-14}$
Cocaine	1	1000	y=0.1359x	0.999	$1.12x10^{-7}$

Table 2. Linear dynamic range of drugs investigated.

2.2 Banknotes

A total of 28 banknotes comprising equal numbers of all the denominations issued; £B1, £B5, £B10 and £B20 notes were kindly donated by the Bristol Pound CIC. These had been in circulation from 2015 to December 2018. Banknotes were handled using nitrile gloves and kept in closed sealed plastic bags in the dark.

2.3 Extraction procedure

Individual banknotes were placed in glass tubes and aliquots of 20 % acetonitrile: formic acid (0.1 %) and an internal standard mix added to each tube. Each tube was then sonicated for 15 minutes. A suitable aliquot of the resulting solution was filtered and introduced to LC/MS/MS.

Results and Discussion

Sample Size Power Calculations

As this is a technical note on how to carry out this type of study a very small number of notes were sampled and we can calculate the post-hoc statistical power on these data, and suggest a minimum sample size required to achieve a 0.8 statistical power. For the differences between denominations we calculate the statistical power of the biggest effect seen, which is between the results for cocaine on £B 5 notes and £B 20 notes, and this current study is found to have a power of only 21.1 %, due to the large standard in cocaine measurements on the £B 20 notes deviation (108.5 µg on a mean of 35.7 µg) and the small sample size (7 notes). To capture an effect of roughly the size seen in this preliminary study at an appropriate statistical power, we would require a sample size of 82 notes per denomination (using standard settings alpha = 0.05, beta = 0.2 and a power of 0.8). If we look at the averages over notes of all denominations for each drug we have a larger sample size of 28 notes. The post-hoc power for cocaine versus ketamine (the most novel and smallest result) is 23.4 %, and the largest result, cocaine versus methamphetamine, has a power of 41.3 %. These powers are too small for this study to be quantitative. Using the cocaine results as the reference group, the sample size required to have sufficient statistical power is between 145 notes per denomination and 280 notes per denomination. This is because the very high variance on the cocaine data. These numbers are the worst-case scenario, using a different drug as the reference increases the post-hoc power calculation and reduces the number of notes needed, however to design a follow-up study one usually wants to consider highest number of samples required to see if that is within achievability.

Distribution of Drugs Based on Denomination and Drug Type

The level of contamination is quite notably different for each of the drugs investigated and there is some correlation with denomination banknotes and the level of drug contamination found (figure 1). Low levels of methamphetamine and MDMA were detected and drug contamination was principally from cocaine and ketamine. The £B1, was found to have the lowest mean contamination for all of the drugs investigated. The higher denomination notes, especially in the case of cocaine, were found to have exhibit the highest contamination levels. Presumably, these notes have been used in drug taking, or have come into close or direct contact.

The £B are generally kept separate from other currencies and contamination via sorting machines and related equipment is unlikely as the volume of £B circulated does not warrant their application [24]. Consequently, we believe that the degree of contamination results from drug usage or contamination from storage in people's wallets and purses.

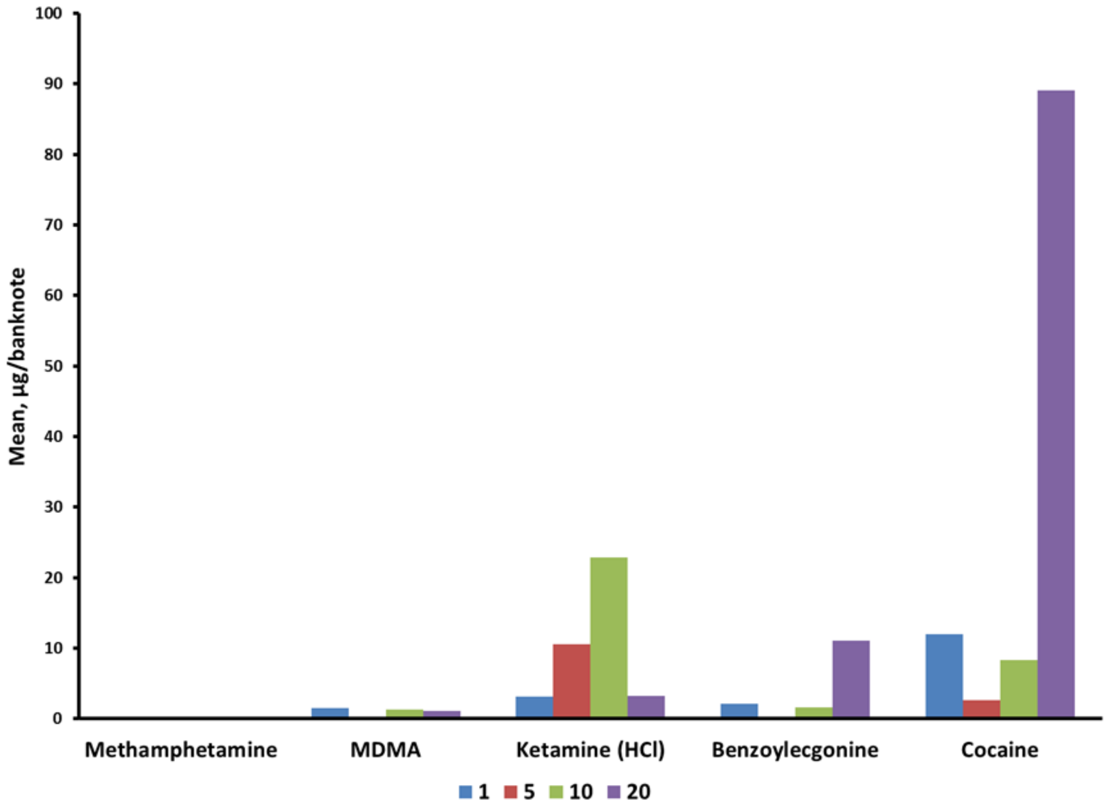

Figure 1. Mean distribution of methamphetamine, MDMA, ketamine, benzoylecgonine and cocaine with relation to £B denomination.

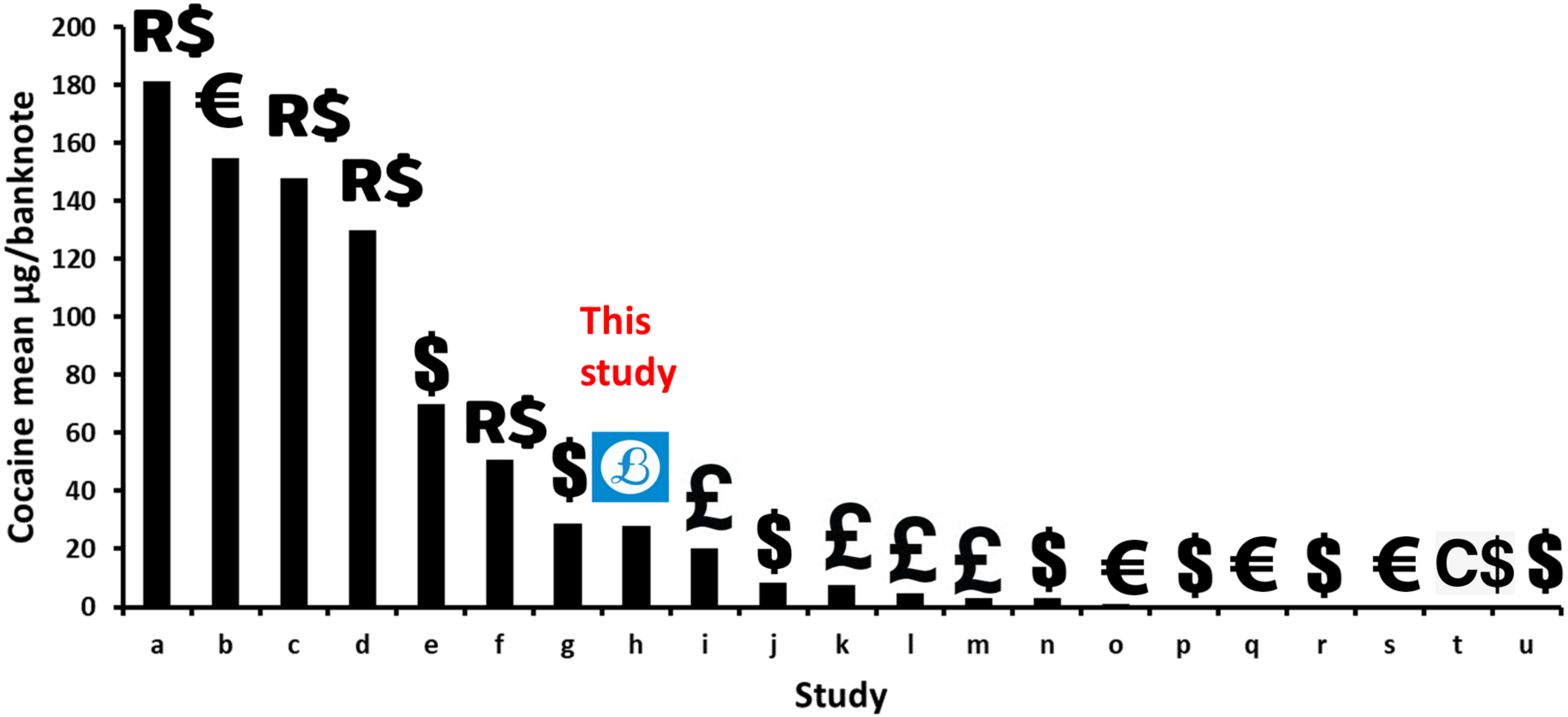

Figure 2. Comparative mean levels of cocaine (µg/banknote) recorded. (a) Heller *et al.* 2013 [25]; (b) Esteve-Turrillas *et al.* 2005 [7]; (c) Rodrigues *et al.* (2013) [21]; (d) Almeida *et al.* 2015 [16]; (e) Oyler *et al.* (1996) [22]; (f) Di Donato *et al.* (2007) [14]; (g) Jenkins (2001) [11]; (h)this study; (i) Johnson 2016 [29]; (j) Zuo *et al.* 2008 [26]; (k) Johnson 2016 [29]; (l) Johnson 2016 [29]; (m) van der Heide *et al.* (2015) [27]; (n) Negrusz *et al.* (1998) [19];(o) Mackuľak *et al.* (2015) [35]; (p) Luzardo *et al.* (2011) [2]; (q) Wimmer and Schneider (2011) [13]; (r) Jourdan *et al.* (2013) [18]; (s) Bones *et al.* (2007) [12]; (t) Hudson (1989) [17]; (u) Song *et al.* (1996) [20].

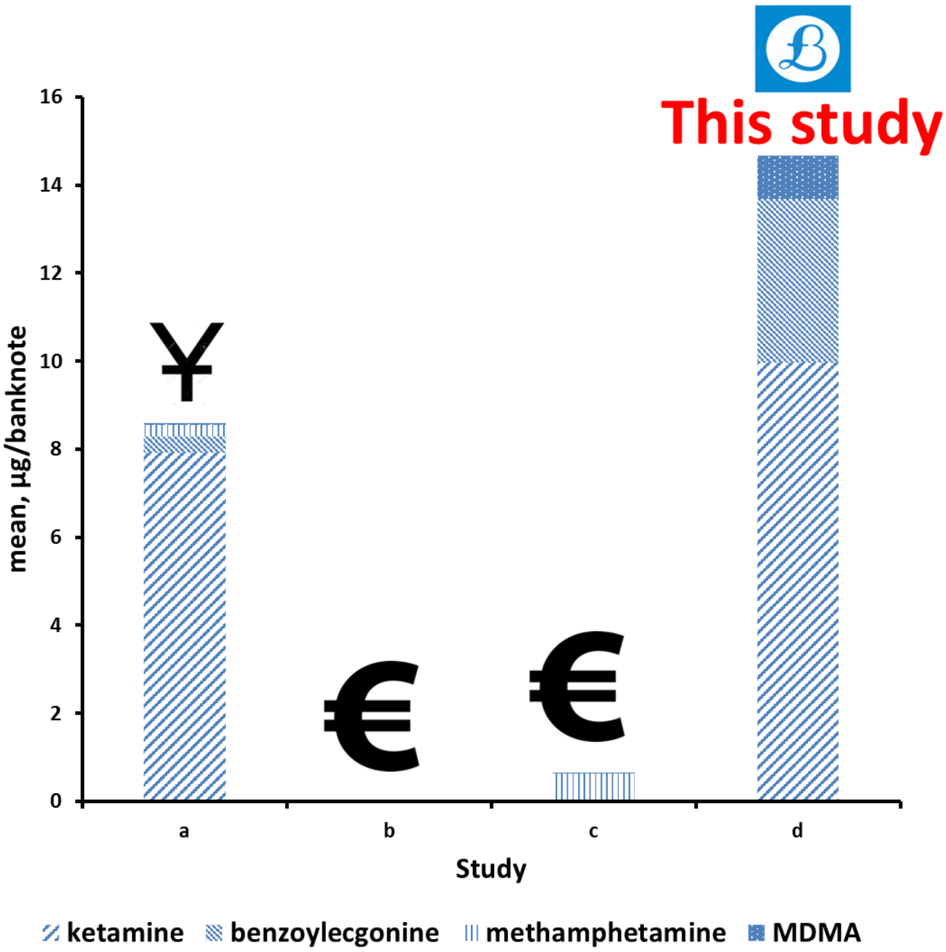

Figure 3. Relative levels of ketamine, benzoylecgonine, methamphetamine and MDMA reported for different currencies. Study: (a) Ieong *et al.* (2015) [28]; (b) Bones *et al.* (2007) [12]; (c) Mackuľak *et al.* (2016) [35]; (d) this study.

Cocaine

In previous studies up to 100 % of all banknotes were reported to be contaminated with cocaine [5,29] with average contamination levels of between 0.118 µg to 148 µg/banknote. However, within these studies, levels as high as 1110 µg [21] and 1330 µg [22] are reported. In this present study, cocaine levels showed an average level of 28.0 µg/banknote (range = 0.102 µg to 534 µg/banknote). As can be seen in figure 2, the level of cocaine contamination sits close to that reported for small number of reports given for the Pound Sterling [29].

Figure 4 shows the distribution of cocaine and benzoylecgonine across all of the £B note investigated. Higher contamination levels were seen associated with the £B 20 notes. One particular £B 20 (20.6) showed notably higher levels of 602 µg of cocaine and benzoylecgonine.

Banknotes contaminated with cocaine were also found to show significant amounts of benzoylecgonine, with a mean of 3.73 µg/banknote and a median of 91.9 ng/banknote. A strong relationship was found between cocaine and benzoylecgonine levels present on the £B notes (R^2 = 0.9870). Due to the good relationship with cocaine levels found, we believe that benzoylecgonine originates from the degradation of cocaine on the banknote. The presence of benzoylecgonine on banknotes has been shown in previous studies [12,13]. It has been shown to be one of the main biology metabolites of cocaine [30], but can also be formed chemically via the hydrolysis [31,32]. However, this does not of course preclude the possibility of it not originating from contamination from sweat and other bodily excretions.

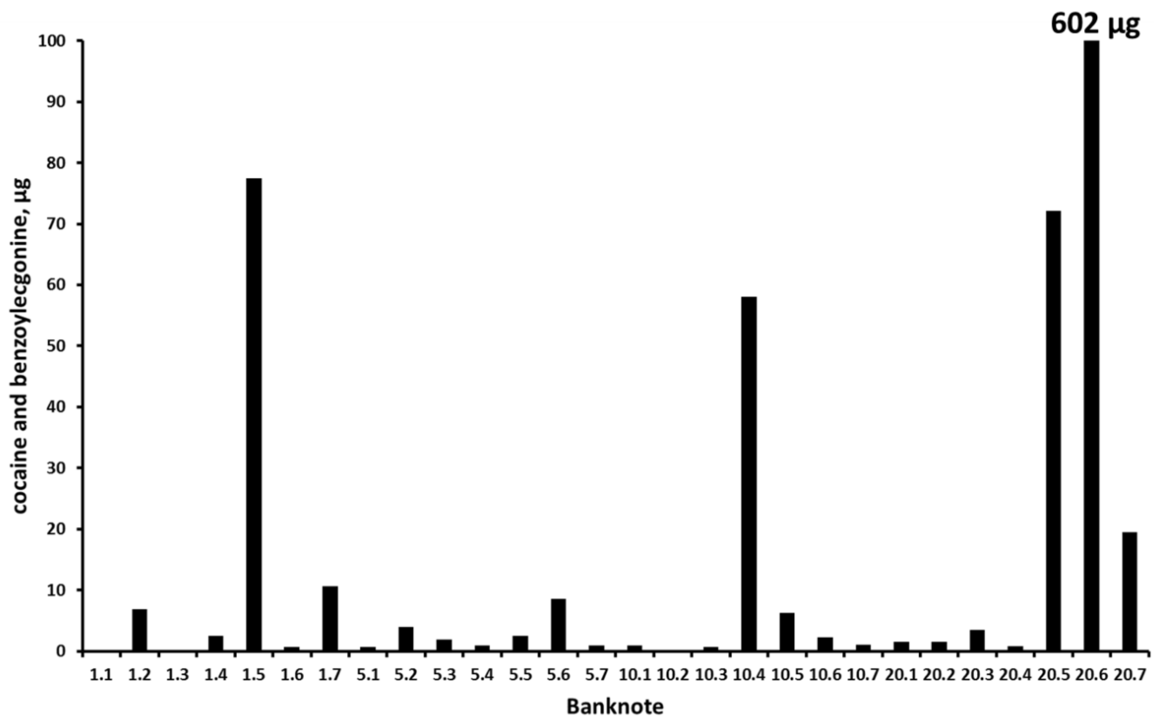

Figure 4. Sum of cocaine and benzoylecgonine in µg/banknote. High cocaine levels were detected on one £B20 note (20.6) as labelled in figure.

Ketamine

To our knowledge, there have only been two reports on the determination of ketamine on banknotes [12,28]. Figure 5 shows the levels of ketamine determined in our study showing a similar prevalence of ketamine, with all of the £B notes sampled being contaminated with ketamine with mean and median levels of 9.95 µg/banknote and 3.44 µg/banknote respectively. Unlike cocaine, ketamine contamination levels were found associated with the £B 10 notes (figure 1).

In 2007, Bones *et al* [12] investigated 45 Irish euro banknotes for 16 illicit drugs including ketamine. Their study did not report the presence of ketamine on any of the notes investigated. However, in a later study in Macao, China, in 2015 Ieong *et al* [28] reported that 98 % of all the banknotes investigated were contaminated with ketamine resulting from the trend of taking ketamine in nightclubs in that area.

A recent report of illicit drug use in 2019 in the neighbouring Principality of Wales [33], ketamine along with cocaine were shown to be the most commonly reported drugs. In this same study, ketamine was found to be the most commonly identified illicit drugs found in nightclub and festival amnesty bins. Similar trends have been shown in Europe, with studies in Munich nightclubs [34] showing 21.2 % of attendees had consumed ketamine in last 12 months.

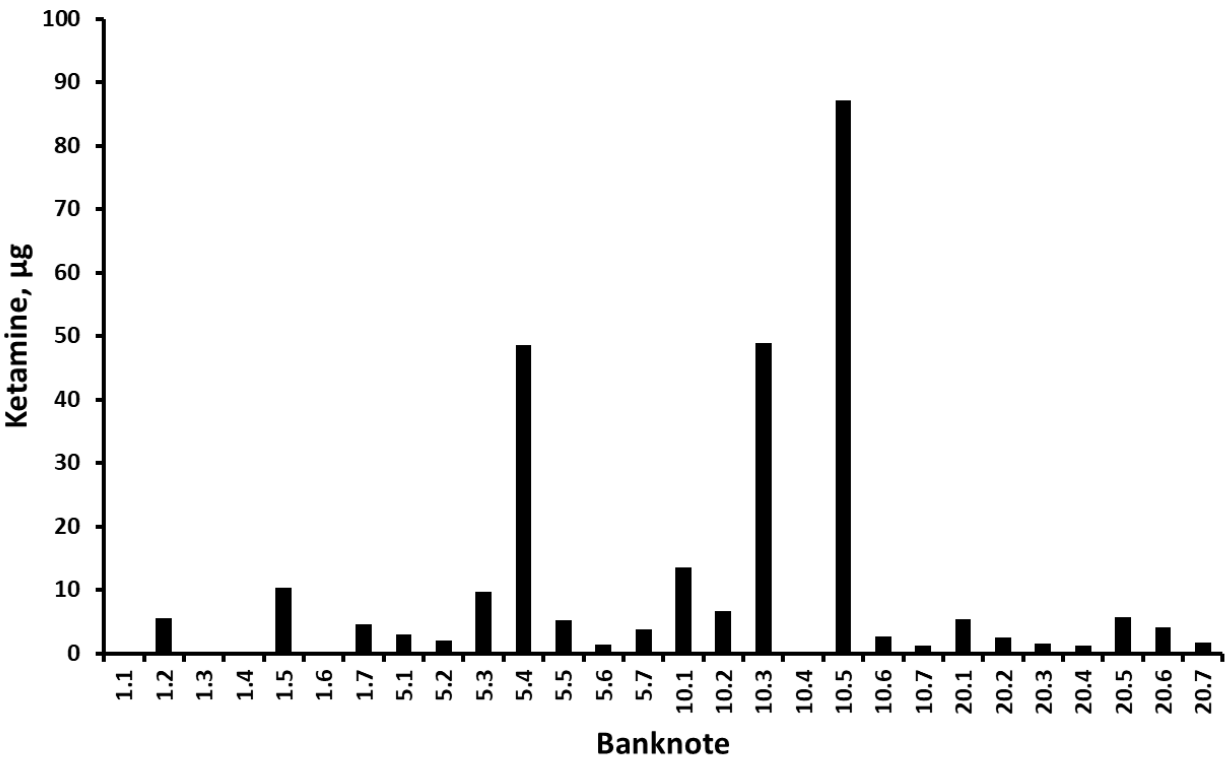

Figure 5. Ketamine HCl µg/banknote.

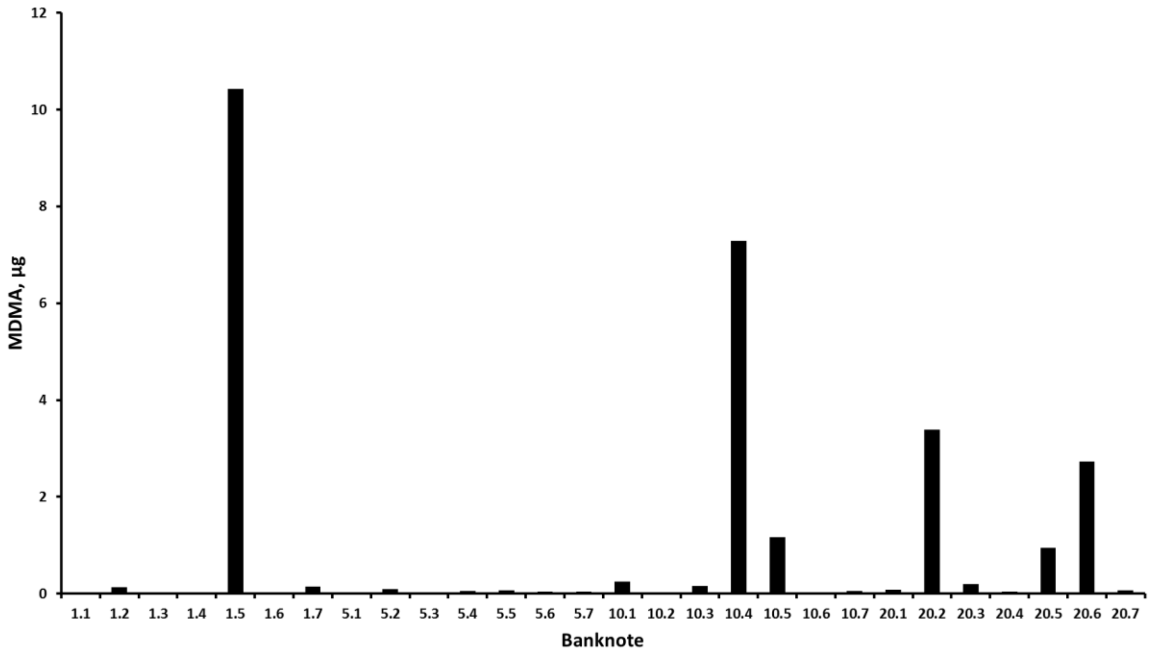

Figure 6. MDMA µg/banknote

MDMA

3,4-Methylenedioxymethamphetamine, often referred to as Ecstasy or MDMA, is normally administered in small doses in tablet form. As a result, only a small number of reports have shown detectable amounts present on banknotes [8,13,35,36]. Wimmer and Schneider [13] reported that MDMA was mainly found on small denominations Euro notes which shows some similarity to the results here with the predominate MDMA level seen for one of the £B1 (1.5). This note also showed a high level of cocaine present as well (figure 4). Similar to the £B10 and £B20 (10.4, 10.5, 20.5 and 20.6) denominations to exhibit elevated levels of MDMA (figure 6), and high levels of cocaine (figure 4). This shows some possible relationship between the usage of MDMA and cocaine. Studies have highlighted MDMA users to be more likely to use other drugs, specifically cocaine [37,38].

Methamphetamine

Depending on its form, methamphetamine can be swallowed, snorted, injected or smoked in its more pure, crystalline commonly referred to as known as crystal meth. Globally, amphetamine-type stimulants are the second most widely used drugs, with use levels often exceeding those of heroin and cocaine [39]. Fultz, *et al.* [15] undertook GC/MS analysis of one-dollar banknotes circulating in the Birmingham, Alabama metropolitan area in 2012 and reported 42 % of these were contaminated with methamphetamine. However, the Bristol Drug Survey [40] reported little usage of methamphetamine in the area. This is reflected in the levels we found for the £B (figure 7). Notably higher levels have been reported in Europe, such as that reported by Mackuak and Gal [35] who showed that banknotes used in the Czech Republic and Slovakia were contaminated mainly by methamphetamine, at levels as high as 940 and 760 ng/note, respectively. However, only two of the £B notes sampled were found to be contaminated with methamphetamine at levels greater than our LOQ (10 ng/banknote). This agrees with a 2011 study by Wimmer and Schneider [13] of 53 Euro banknotes which showed low levels of methamphetamine (median: 7 ng/banknote), with 80 % of these with quantities beneath 15 ng/banknote. Only three Euro notes investigated showed levels greater than 100 ng methamphetamine/banknote. Notably, the £B 10 note, 10.5 has the highest level of both methamphetamine (figure 7) and the highest contamination of ketamine (figure 5). Reports have shown that ketamine has been used as an adulterating agent for methamphetamine [41] which could possibly explain this relationship.

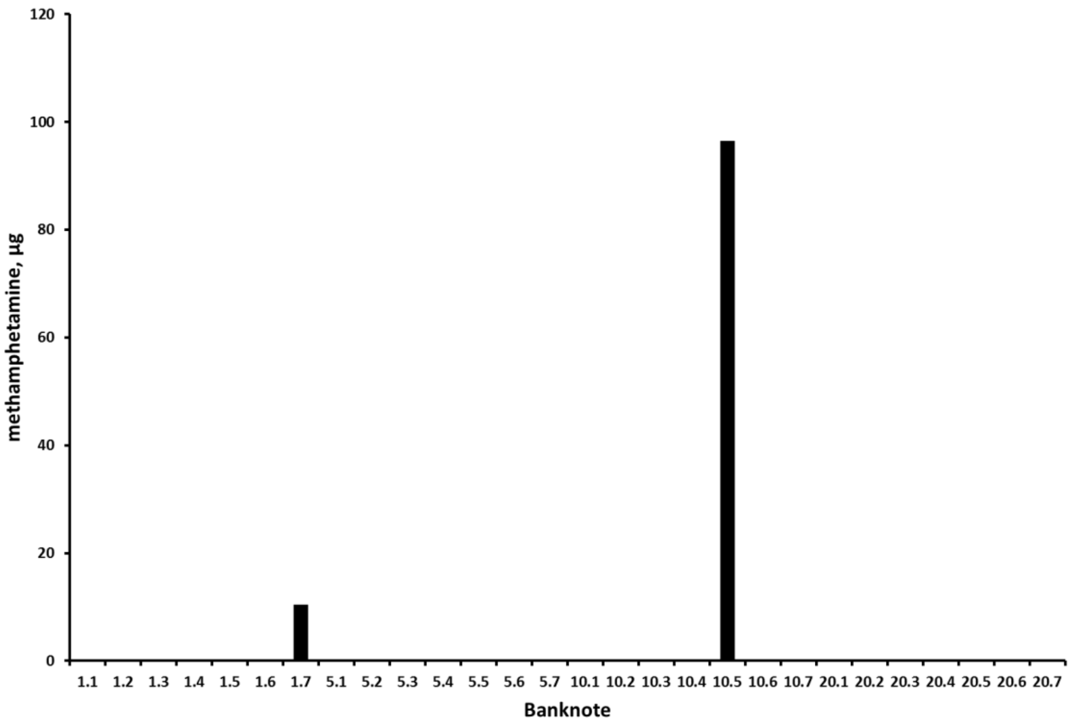

Figure 7. Methamphetamine µg/banknote.

4. Conclusions

This preliminary LC–MS/MS study has been successfully employed for the determination of five illicit drugs of abuse on £B banknote for the first time. All circulating denominations of the £B were investigated. Bristol Pound banknotes are circulating only within the Bristol area at a known number of outlets. Consequently, geographical and sociological conclusions can be made with a greater degree of certainty compared to studies undertaken on currency circulating in larger geopolitical areas. Statistical analysis of the results from this initial study has identified the sample numbers that would be required for a further investigation.

Cocaine represented the predominate contamination, with up to 500 µg/banknote, mostly associated with the £B 20 notes, the highest domination in circulation. Notably, ketamine with levels of up to 80 µg/banknote were found; principally focused on the £B 10 notes. To our knowledge, this is only the second report of such levels of ketamine. Those exhibiting elevated levels of MDMA (up to 10 µg/banknote) showed similar high levels of cocaine. Only two of the 28 banknotes examined were found to be contaminated at levels above the LOQ (10 ng/banknote) with methamphetamine. This to a large extent reflects what has been reported in previous studies on other currencies. However, the levels of ketamine found associated with the £B in this study have not be previously reported outside of China.

The levels of contamination of the £B notes was found to fit into three board groups. Those contaminated at low levels were believed to have originated from contamination from contact with other notes and represent a background level. A smaller set of medium level contaminated notes were believed to have resulted from the taking of drugs, in some point in the past. The third set with high contamination levels were thought to have resulted from their use in recent drug taking.

To our knowledge studies have focused on mainly on cocaine, MDMA and methamphetamine and there has been no investigations focused on the possible contamination of banknotes by emerging new psychoactive substances. Similarly, recent studies have highlighted changes in drug usage and composition, with increased usage of fentanyl [42] and increasing potency of THC in cannabis derived products [43]. We believe that these would be important areas of future investigations which could be combined with a study of wastewater drug levels or self-reporting questionnaire of Bristol Pound users.

Author Contributions

Kevin C. Honeychurch: Conceptualization, Methodology, Writing- Review, Editing, Supervision. Freya Bryant, Samuel Codd, Sophie Hudd, Reece Longden: Data curation. Paul Bowdler: Supervision, Methodology and Data curation. Ella Gale: Statistical analysis and Writing. Paul White: Statistical analysis.

Declaration of competing interest

Authors declare there is no conflict of interest.

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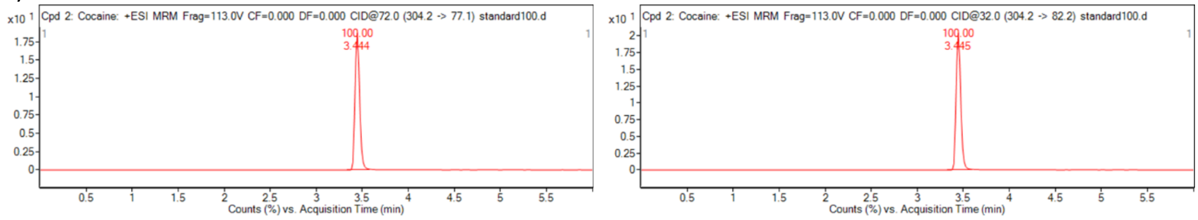
Supplementary Material

(a)



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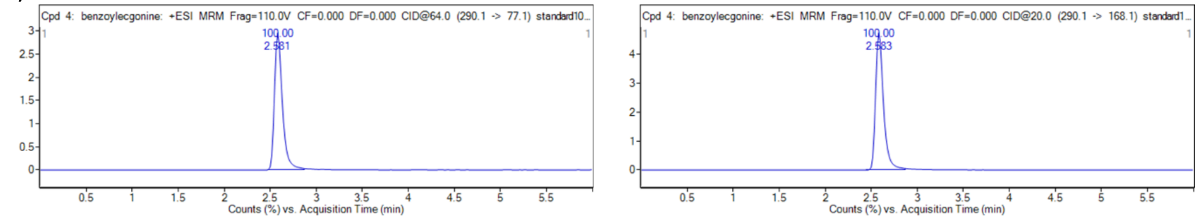

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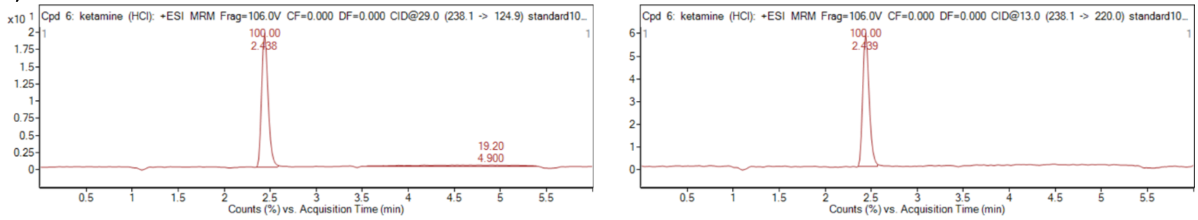

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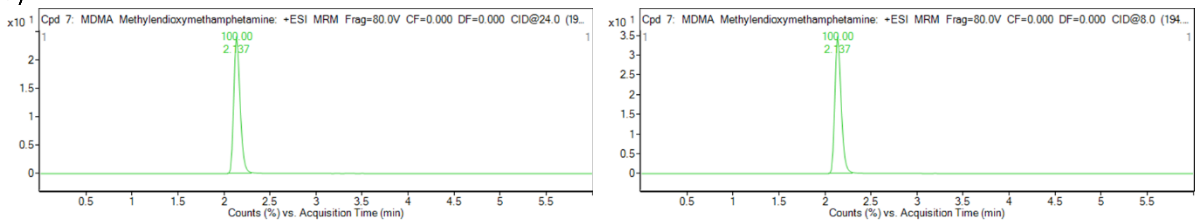

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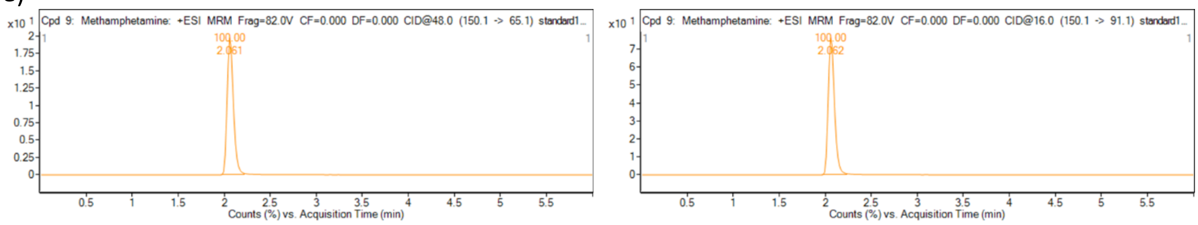

Figure S1. Typical LC/MS/MS chromatograms of (a) cocaine; (b) benzoylecgonine; (c) ketamine HCl; (d) MDMA and (e) methamphetamine.

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