



## Research Paper

# When does the cutting of cocaine and heroin occur? The first large-scale study based on the chemical analysis of cocaine and heroin seizures in Switzerland

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## ABSTRACT

**Background:** Illicit drug profiling can provide knowledge about illicit drug markets, informing on the level of distribution and its evolution in space and time. Illicit drug profiling is usually limited to impurities originally present in the illicit drug (e.g. alkaloids, co-extracted compounds or by-products). However, the benefit of a comprehensive analysis of cutting agents in drug seizures for law enforcement agencies, intelligence and health policy has not been thoroughly investigated in the literature and is the focus of this research.

**Aim:** This research aims at assessing when and how cutting (i.e. adulteration and dilution) occurs in the supply chain by analysing cocaine and heroin seizures made between 2006 and 2015 in Switzerland.

**Methods:** Cocaine and heroin seizures made along the supply chain by law enforcement agencies in the Western region of Switzerland were investigated for adulteration and dilution. A total number of 7841 cocaine and 3476 heroin specimens coming from 1341 and 721 seizures, respectively, were analysed.

**Results:** The results show that, for both illicit drugs, adulteration and/or dilution occur before arrival into Switzerland as well as in Switzerland. While cocaine is adulterated and diluted, heroin is only adulterated. Interestingly, the same mixture of adulterants (i.e. caffeine-paracetamol) is used to cut heroin at each step in the supply chain.

**Conclusion:** Gaining knowledge about adulteration and dilution at different stages in the supply chain enhances our understanding of drug markets. It also highlights differences along the supply chain and in the distribution of both drugs in Switzerland.

## Introduction

Chemical analysis of illicit drugs can serve different purposes in forensic science. Its primary use is to investigate a particular case which is the traditional path followed by most laboratories. It involves the illicit drug identification and purity determination for Court purposes. Its secondary use is to infer a series of crime. Seizures can be linked through physical or chemical profiles and support the actions of law enforcement agencies at a tactical or operational level. Its tertiary use is to provide knowledge about crime phenomena and illicit drug networks, informing on the level of distribution and its evolution in space and time (Esseiva et al., 2007). The knowledge obtained through the chemical analysis of illicit drug seizures has the potential to supplement and complement law enforcement data, economical, criminological and

epidemiological studies to support intelligence-led policing strategies (Broséus, Baechler, Gentile, & Esseiva, 2016; Morelato et al., 2013; Ribaux, Crispino, & Roux, 2014). In this perspective, forensic intelligence provides insights into criminal activity (Morelato et al., 2014). This additional contribution of forensic science will be investigated in this article through the analysis of cocaine and heroin cutting agents.

In addition to organic impurities, cutting agents may be present in a drug specimen. Cutting agents refer to adulterants (i.e. pharmacologically active substances such as caffeine, paracetamol, etc.) and diluents (i.e. pharmacologically inactive substances such as mannitol, lactose, etc.) (Broséus, Baechler et al., 2016; United Nations, 2001). The use of alkaloid profiles for intelligence purposes has been studied for many years (Broséus, Baechler et al., 2016; Broséus, Huhtala, & Esseiva, 2015;

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Esseiva, 2004; Esseiva, Dujourdy, Anglada, Taroni, & Margot, 2003; Esseiva, Gaste, Alvarez, & Anglada, 2011; Esseiva et al., 2007). Although the frequency and health effects of cutting agents have been reported in the literature (Broséus, Gentile, Gentile et al., 2015; Broséus, Gentile, & Esseiva, 2016; Cole et al., 2010), the patterns related to adulteration and dilution (e.g. the use of particular combination of substances) and the level at which they occur in the supply chain have attracted little attention. The path taken by a product from production to consumption is called the supply chain (Wilson & Stevens, 2008). It involves social networks in which several people engage in this illegal activity (Desroches, 2007). There is little consensus in the literature as to what constitutes upper and intermediate level drug trafficking. The upper level may include importers who have connections in source countries. The intermediate level may include distributors or wholesalers, described as dealers who purchase drugs in large quantities and sell them to other dealers down the chain. Cutting agents may be added at different stages and can be considered as indicators to inform on the structure and organisation of illicit drug markets. According to the literature (Broséus, Gentile, Gentile et al., 2015; Coomber, 1997a, 1997b, 1999), adulteration of cocaine and heroin occurs before exportation, during transit or just after importation. This may be related to the limited availability and the high cost of adulterants at street level (Broséus, Gentile et al., 2016; Maietti, Castagna, Molin, Ferrara, & Traldi, 2009). In the late 90s and early 2000s, Coomber et al (Coomber, 1997a, 1997b, 1999; Coomber & Maher, 2006) investigated when cutting of heroin took place based on interviews of drug dealers at different levels in the supply chain. They found that adulteration and dilution was not systematic before reaching the consumers and if heroin was cut, dealers would mainly use diluents. Dujourdy et al (Dujourdy, Besacier, & Ladroue, 2010) analysed cocaine specimens seized at airports and on the street in France from 1990 to 2009. According to their analysis, diltiazem, hydroxyzine and levamisole appeared to be added in the country of production while phenacetin, procaine and lidocaine was added after importation in Europe. Caffeine may be added before or after importation.

There is limited empirical data available in the literature about the composition of cocaine and heroin specimens (including the number and purity of cutting agents) seized at different levels of the supply chain in the country of destination. In 2010, Cole et al. (Cole et al., 2010) examined the adulteration of several illicit drugs, including cocaine and heroin through the systematic collection of relevant peer reviewed literature and case reports. Based on their review, they argued that “(...) the evidence suggests that the majority of adulteration of heroin takes place at or close to the time of synthesis and significantly less ‘cutting’ than would be generally perceived takes place after heroin leaves the country of origin”. This ‘evidence’ is principally based on differences in purity between specimens seized at the border and street specimens seized in the country of destination. However, this type of analysis should be combined with the number, frequency and, if available, the concentrations of adulterants/diluents at each stage of the supply chain in order to properly investigate this hypothesis. This research aims at assessing when and how cutting occurs in the supply chain by analysing cocaine and heroin seizures made between 2006 and 2015 by law enforcement in the Western region of Switzerland. This study builds on previous work related to the analysis of cutting agents (Broséus, Gentile, Gentile et al., 2015) and highlights the benefit of this analysis for law enforcement agencies, intelligence and health policy. The usefulness of the information extracted from cutting agents to understand drug markets has never been studied. It has the potential to complement previous studies on alkaloid profiles and shed new light on the distribution of cocaine and heroin in Switzerland.

## Method

### *Cocaine and heroin data*

The study relied on cocaine and heroin data analysed by a centralised laboratory hosted in the School of Criminal Justice (ESC) at the University of Lausanne. These datasets were used in previous studies (Broséus, Baechler et al., 2016, 2015a; Broséus, Gentile et al., 2015). From 2006 to 2015, 7841 cocaine and 3476 heroin specimens coming from 1341 and 721 seizures, respectively, were analysed. These seizures were made by police departments, federal police, border guards and customs officers in Western Switzerland. The illicit drug purity, presence of cutting agents and chemical profiles based on natural, co-extracted or by-product compounds were extracted for each specimen. The profiling methodology (sampling procedure, solvent extraction, gas chromatography-mass spectrometry analysis) for both cocaine and heroin was thoroughly described in previous studies and won't be repeated in this article (Broséus, Debrus, Delémont, Rudaz, & Esseiva, 2013, 2015a; Esseiva et al., 2005, 2003; Esseiva et al., 2011; Ioset et al., 2005). It is, however, important to mention that cutting agents were reported as present or absent and were not quantified.

Chemical results (e.g. purity, chemical profiles and adulterants/diluents) were collated and organised in a memory, along with physical (e.g. packaging and appearance of the drug specimen) and circumstantial information (e.g. case number, mass of the specimen, data and place of the seizure). In contrast to a database, the memory is systematically structured to help form meaningful outcomes. For example, seizures are not stored individually but are collated and grouped in classes according to chemical similarities. For the purpose of this study, the illicit drug purity, presence/absence of cutting agents, the packaging and the mass of drugs seized were used for the analysis.

### *Cocaine and heroin cutting agents*

The supply chain of cocaine and heroin is relatively complex since the drugs go through multiple people from the production to the end user (e.g. producer, trafficker, wholesaler, retailer and consumer). According to Caulkins and Reuter (Caulkins & Reuter, 1998) who studied drug prices in the United States in 1998, there might be five or six separate sale transactions between importation and final sale on the street. The mass of illicit drug gets smaller the further down in the supply chain while the prices increase (Caulkins & Reuter, 1998; Kilmer & Hoorens, 2010). However, clearly distinguishing between wholesale and retail level is a difficult task. Considering the mass and packaging of cocaine and heroin specimens, it is possible to hypothesise their belongings to the different levels in the supply chain. In this study, the mass of illicit drug specimens was considered when analysing the trends in adulteration and dilution, in particular when (i.e. at which stages of the supply chain) and how (i.e. number and type of cutting agents) cutting occurred in heroin and cocaine specimens.

Data analysis and visualisation were conducted using R® (The R Foundation for Statistical Computing, version 2.15.1), Microsoft Excel (Microsoft Corporation, version 15.31) and Tableau Software Professional Edition v. 2018.2.

## Results and discussion

### *Trafficking of heroin and cocaine into Switzerland*

The main trafficking routes of heroin into Switzerland are presented in Fig. 1. While most branches of the Balkan route were once under the influence of Turkish criminal groups, a shift occurred in the 1990s leading to Albanian groups gaining market shares, in particular in destination countries such as Italy, Greece and Switzerland. Albanian groups generally purchase from Turkish wholesalers and once in Albania, shipments may get stored, cut with adulterants and/or

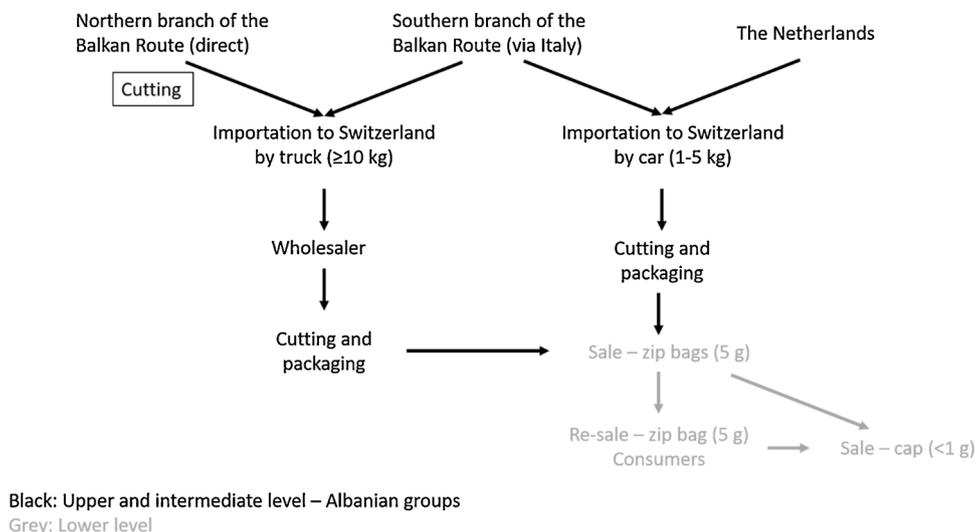


Fig. 1. Main trafficking routes of heroin into Switzerland.

repackaged (United Nations Office on Drugs & Crime, 2014). It is estimated that 20–25 tons of heroin pass through Albania from Macedonia before heading to Italy (by sea) and Switzerland (United Nations office on Drugs & Crime, 2010; Zhilla & Lamallari, 2015). Heroin trafficking in Europe is organised by different groups that operate in different European regions. In Switzerland, Albanian groups have dominated the heroin market for the last twenty years (Zobel, Esseiva, Udrisard, Lociciro, & Samitca, 2017). These groups presumably dominate the import and/or wholesale level as well as the intermediate level (until the sale in zip bags of 5 g, see Fig. 1), with a more varied retail distribution (Zobel et al., 2017).

The main trafficking routes of cocaine into Switzerland are presented in Fig. 2. Trafficking of cocaine from South America into Europe appears to take place through Spain and Portugal in the south and the Netherlands and Belgium in the north (European Monitoring Centre for Drugs & Drug Addiction, 2016a). A large number of wholesalers are present in these entry points and wholesalers in Switzerland can obtain their products through many supply sources, leading to a diversity of products entering the Swiss market. According to interviews with police officers, the Igbo people (an ethnic group native to south-central and south eastern Nigeria) dominate the cocaine market in Switzerland (Zobel, Esseiva, Udrisard, Lociciro, & Samitca, 2018). This group is characterised by its presence all along the supply chain (from

exportation to street level). In contrast to the Albanian groups, other groups are also involved in the cocaine market (groups coming from other West African countries, Latin America, Albania, Western Balkan countries, North Africa, Lebanon, European countries and Switzerland).

Supply chain

Fig. 3 represents the proportion of cocaine and heroin seizures and specimens (i.e. a seizure may contain several specimens of different masses) of different mass range. The majority of seizures analysed weighed approximately 100 g since seizures submitted for chemical analysis are mainly related to serious offences. Nevertheless, the majority of specimens (which can be multiple within a seizure) weighed less than 15 g. It can be assumed that lower masses - specimens weighing less than 1 g - are related to personal consumption (Broséus, Baechler, & Esseiva, 2017, 2016a; Broséus, Huhtala et al., 2015; Ioset et al., 2005). The categories represented in Fig. 3 are different for cocaine and heroin as the sale units in Switzerland differ for both drugs. According to Zobel et al. (Zobel et al., 2017, 2018), a typical dose of heroin and cocaine in Switzerland weighs less than 1 g. At the next level in the supply chain, cocaine is found in packages of approximately 10 g while heroin is packaged in small zip bags of 5 g (see Figs. 1 and 2).

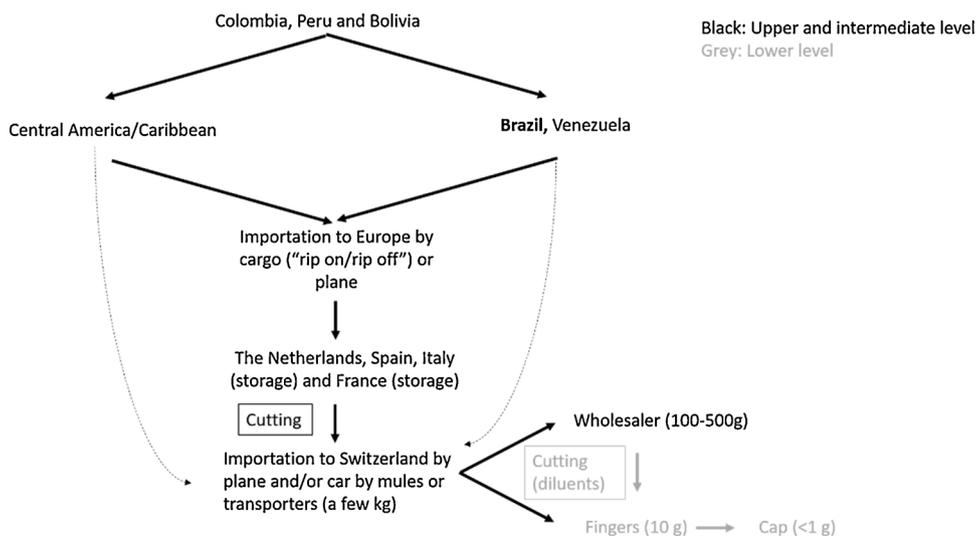


Fig. 2. Main trafficking routes of cocaine into Switzerland.

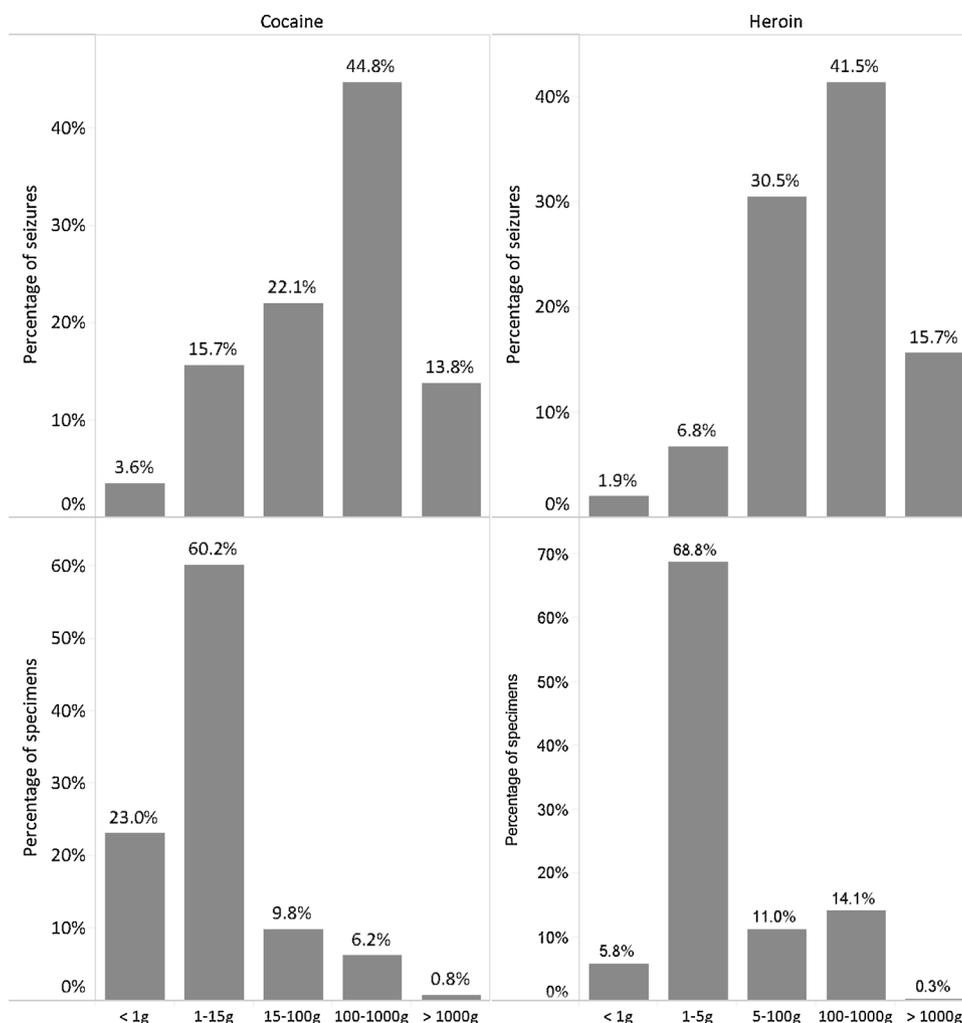


Fig. 3. Proportions of cocaine (left) and heroin (right) seizures (top) and specimens (bottom) of different masses. Note that 3.6% of heroin seizures had no mass recorded and are not represented on this figure.

Analysis of cutting agents – type, frequency and combination

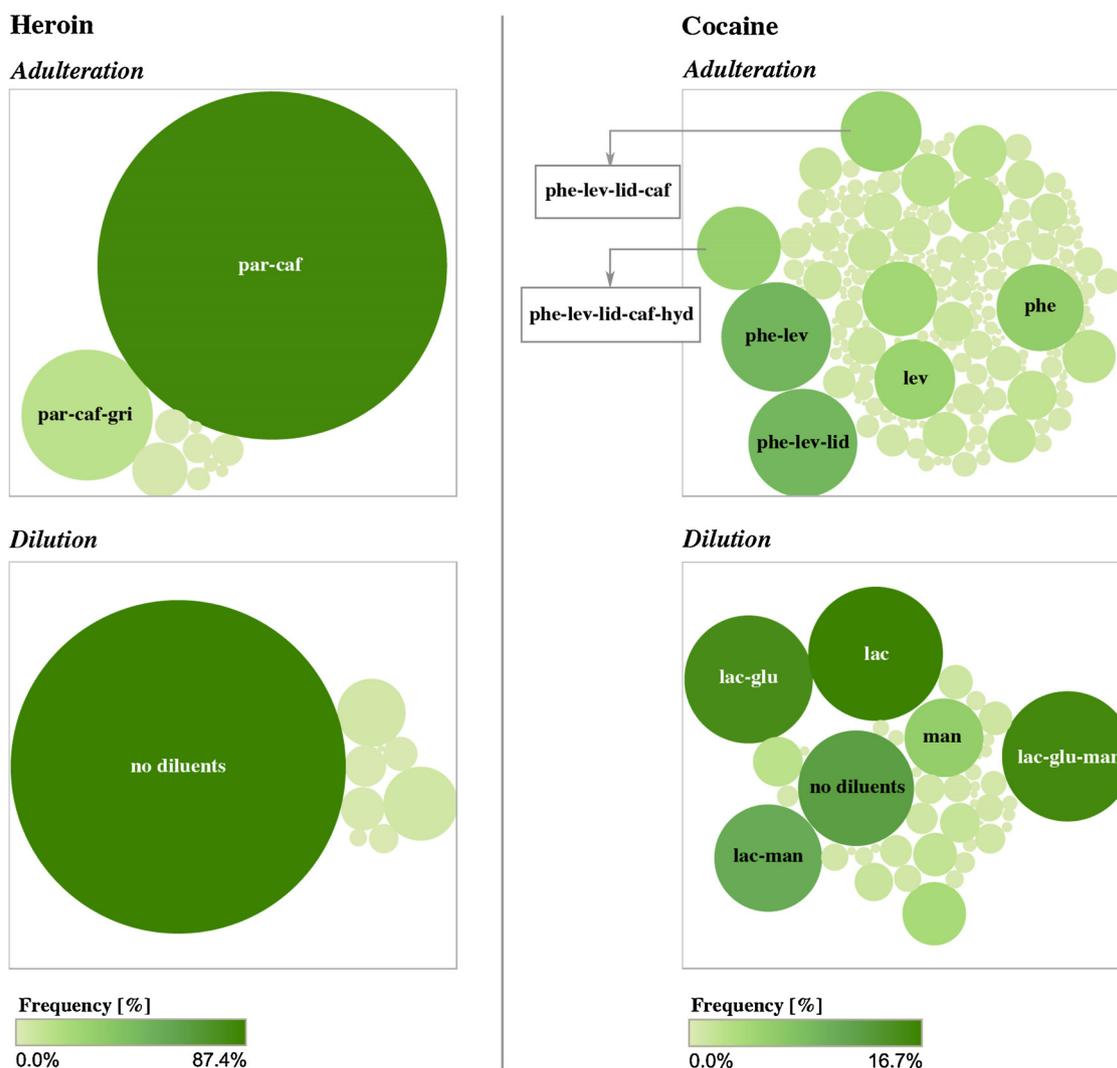
The majority of cocaine and heroin specimens contained at least one adulterant irrespective of their mass (precisely, 97% of cocaine specimens and 99% of heroin specimens). While cocaine adulteration was diverse, heroin adulteration was more homogeneous (see Table 1). More than 90% of the heroin specimens seized were adulterated with either caffeine and/or paracetamol, irrespective of the mass of the specimen. In particular, three adulterants were detected on average in cocaine specimens and two in heroin specimens. A similar observation was highlighted for diluents. Eighty-eight percent of cocaine specimens were diluted using mainly lactose and to a lesser extent glucose and mannitol whereas only 15% of heroin specimens analysed contained diluents.

Fig. 4 represents the most frequent combinations of adulterants (top) and diluents (bottom) detected in heroin (left) and cocaine (right)

Table 1  
Number of adulterants and diluents detected in cocaine and heroin specimens.

	Number of adulterants detected				Number of diluents detected			
	Min	Average	Max	Standard deviation	Min	Average	Max	Standard deviation
Heroin	0	2	5	1	0	0	4	1
Cocaine	0	3	9	2	0	2	6	1

specimens. The type of adulterants detected and their proportions are in line with substances detected in different European countries in cocaine (Andreasen, Lindholm, & Kaa, 2009; Broséus, Gentile et al., 2015; Brunt et al., 2017, 2009; Dujourdy et al., 2010; Kudlacek et al., 2017; Schneider & Meys, 2011) and heroin specimens (Andreasen et al., 2009; Broséus, Gentile et al., 2016, 2015b; Chaudron-Thozet, Girard, & David, 1992; Kaa, 1994; Schneider & Meys, 2011). Heroin adulteration consisted almost exclusively in caffeine and paracetamol. These two substances have been known to be the main adulterants in Europe since the beginning of the 1990s (Broséus, Gentile et al., 2016; Cole et al., 2011). Caffeine appears to be important as it causes heroin to vaporise at a lower temperature, a practical benefit for users smoking or inhaling heroin. Paracetamol is easy to purchase and has a bitter taste similar to heroin that may disguise poor quality heroin (United Nations Office on Drugs & Crime, 2009). In contrast, levamisole, phenacetin, caffeine and lidocaine were frequently encountered in cocaine specimens, as well as diluents such as lactose. From a Swiss perspective, the combination of adulterants was limited for heroin and dilution was almost non-existent. Therefore, the detection of links between different seizures based on adulterant profiles would be of limited value for investigative and intelligence purposes if these two adulterants did not change over time. Supplementary information, such as the concentrations of adulterants would be necessary to highlight clusters and specific patterns of adulteration. For cocaine, the most frequent combination of adulterants was found in less than 10% of all cocaine specimens. This diversity may be linked to the physical appearance of cocaine (white powder) or it may



**Adulterants:** caf = caffeine ; gri = griseofulvin ; hyd=hydroxyzine ; lev = levamisole ; lid = lidocaine ; par = paracetamol ; phe = phenacetin  
**Diluents:** glu = glucose ; lac = lactose ; man = mannitol

**Fig. 4.** Most frequent combinations of adulterants (top) and diluents (bottom) in heroin specimens (left) and cocaine specimens (right).

reflect the market structure in Switzerland that seems to be more complex and dynamic for cocaine than for heroin. Zobel et al. highlighted more diverse consumers, groups and networks involved in the trafficking of cocaine in comparison to heroin trafficking (Zobel et al., 2017, 2018). The combination of cutting agents observed in cocaine specimens could thus be used to reveal distribution networks, similar to the chemical profiling based on alkaloids (Broséus, Baechler et al., 2016).

#### Cutting agents vs supply chain

##### When does cutting occur in the supply chain?

The percentage of specimens containing adulterants and diluents was slightly different depending on the level in the supply chain. At the distribution level (i.e. specimens weighing more than 15 g for cocaine and more than 5 g for heroin), 90% of cocaine and 94% of heroin specimens contained adulterants. At the consumption level (i.e. specimens weighing less than one gram for cocaine and less than 5 g for heroin), 95% of cocaine and 99.8% of heroin specimens contained adulterants. Concerning dilution, 72% of cocaine and 13% of heroin specimens were diluted at the distribution level, while 94% of cocaine and 11% of heroin specimens were diluted at the consumption level. These percentages indicate that the majority of cocaine and heroin

specimens were adulterated before reaching the consumption level. Similarly, a relatively large proportion of cocaine specimens were diluted at masses corresponding to the distribution level. While cocaine was cut with both adulterants and diluents throughout the supply chain, heroin seems to be only adulterated and rarely diluted regardless of the level in the supply chain.

Fig. 5 represents the change in the number of cutting agents along the supply chain for both cocaine and heroin. It shows the change in median purity according to the mass of specimens seized since 2006.

A decrease in median purity was observed when moving towards the consumption level for both illicit drugs. In regard to cocaine, the decrease in purity was particularly significant at two stages. The first drop in purity occurred between specimens weighing more than one kilogram and specimens weighing more than fifteen grams. This decrease seems to be linked to the addition of adulterants and diluents since the number of the respective substances detected in the specimens increased. Although significantly lower than the first drop, the second decrease in purity appeared when specimens weighed less than fifteen grams. This decrease seems to be the result of an addition of diluents only (the number of adulterants remained constant). The addition of diluents (in particular baby formula containing lactose) at this stage was also reported in interviews with consumers and an informant (Zobel et al., 2018). The informant reported that this step was essential

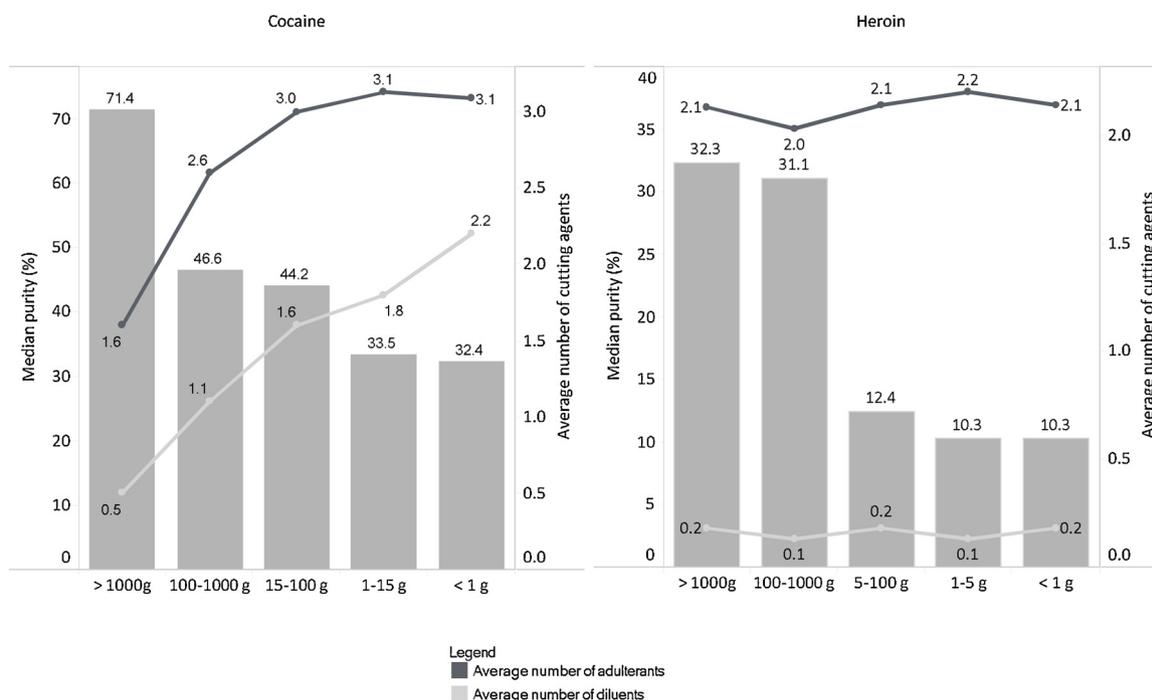


Fig. 5. Evolution of the median purity (grey bars – left scale) and average number of adulterants (dark grey lines, right scale) and diluents (light grey lines, right scale) in cocaine and heroin specimens seized in Western Switzerland since 2006.

to gain enough profit from sales. In contrast, there was little difference in purity between specimens weighing between 1 and 15 g and less than 1 g. According to interviews with street retailers and consumers, cutting agents are rarely added at this stage (Zobel et al., 2018).

Interestingly, the median heroin purity was already low (< 35%) when it entered Switzerland (> 1000 g). According to the United Nations, heroin may be adulterated and repackaged in South-Eastern Europe, as there have been official reports of processing facilities in Greece and repackaging/storage activities in Albania, Kosovo and Macedonia. This may indicate that large-scale heroin adulteration for the export market takes place in the region (United Nations Office on Drugs & Crime, 2014). Once in Switzerland, the major decrease in purity was observed between specimens weighing more than 100 g and specimens weighing less than 100 g. This decrease in purity did not occur in parallel with an increase number of cutting agents. Since the average number of diluents was less than 1 at all levels, adulteration using the same adulterants used before importation into Switzerland must have been responsible for the decrease in purity. Interviews with law enforcement personnel in Switzerland revealed that adulteration with this mixture is conducted at an intermediate level (after importation and storage) (Zobel et al., 2017). The reasons why it occurs at this stage are unknown. Little is known about the trafficking of cutting agents already pre-mixed (e.g. caffeine-paracetamol); however, it is estimated that the trafficking of this mixture could represent a revenue of one to two millions Swiss francs in Switzerland. Finally, there was no purity difference between specimens weighing less than 1 g and specimens weighing between 1–5 g. According to interviews with heroin consumers that also sell part of what they bought, no further cutting is conducted before re-packing it in smaller quantities (Zobel et al., 2017). Although the study was conducted in another country, these results are in line with Coomber & Maher (Coomber & Maher, 2006) who interviewed heroin street dealers in Sydney in 2002. According to the interviews, cutting was not systematic before reaching the customers and if heroin was cut, the dealers would mainly use diluents, such as sugars.

#### Combination of cutting agents at each stage of the supply chain

Figs. 6 and 7 represent the frequency of specific adulterants (top)

and diluents (bottom) for each mass category in cocaine and heroin specimens, respectively.

In Fig. 6, the decrease in purity between specimens weighing more than one kilogram and specimens weighing less than one kilogram was linked to an increase in the frequency of phenacetin and levamisole, the two main adulterants of cocaine seized in Western Switzerland. To a lesser extent, the frequencies of lidocaine and caffeine also increased. The number of specimens containing these four adulterants continued to gradually increase down the supply chain, apart from the transition to the consumption level. It may thus be assumed that these four substances were added at different levels of the supply chain (i.e. at the distribution, intermediate and consumption level). In contrast, the frequencies of other adulterants (e.g. hydroxyzine, procaine and diltiazem<sup>3</sup>) appeared to be stable over the different steps of the supply chain (i.e. they did not change drastically from one mass category to another). It is possible to infer that these substances were added at an early stage of the supply chain (e.g. in the country of production or transit, before importation into Switzerland or just after importation into Switzerland). Interestingly, Broséus et al (Broséus, Gentile et al., 2015) reported that 10% of the seizures received for analysis at ESC contained only adulterants. Common adulterants seized include caffeine, phenacetin and lidocaine. However, no levamisole, diltiazem, hydroxyzine or procaine were seized which tend to confirm their addition before importation into Switzerland. In addition, levamisole is widely used in South America and it is likely that adulteration also takes place immediately after production or just before exportation (European Monitoring Centre for Drugs & Drug Addiction, 2016b; European Monitoring Centre for Drugs & Drug Addiction-Europol, 2010).

While adulteration only occurred in specimens weighing more than 15 g, dilution (in particular with substances such as lactose, glucose and to a lesser extent mannitol) occurred at all levels in the cocaine supply chain.

<sup>3</sup> While an important adulterant from 2007 to mid-2009, diltiazem was almost not detected in 2015, similarly to other countries (Lahaie, 2012; Stambouli & El Bouri, 2017).

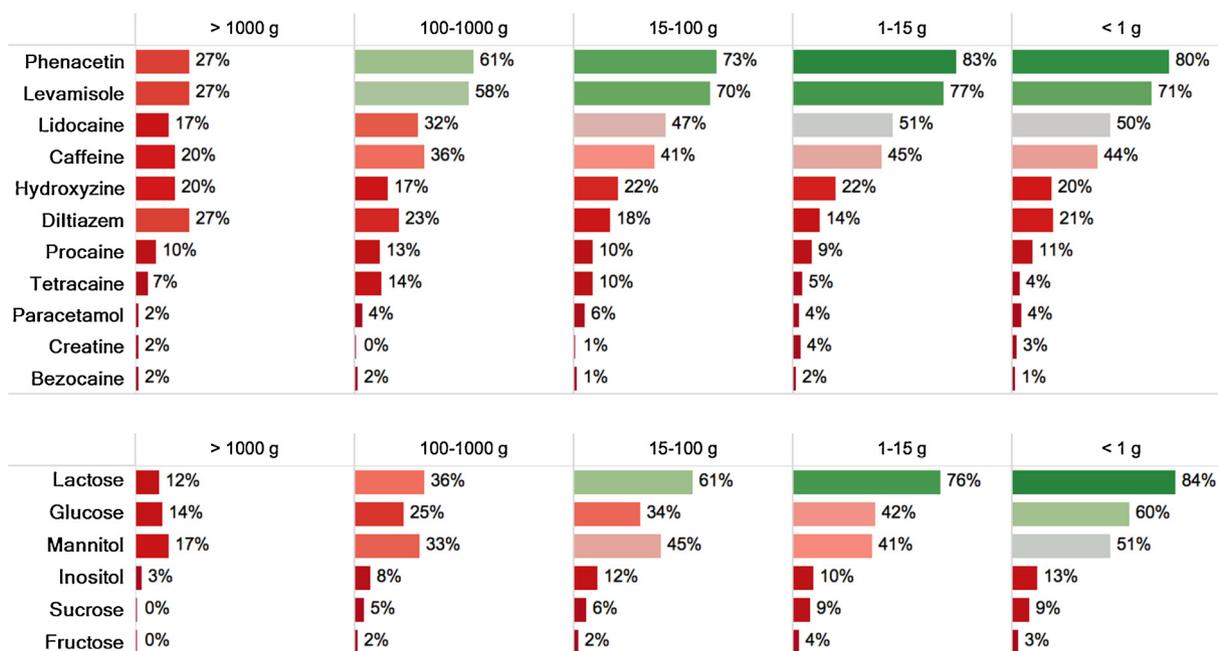


Fig. 6. Frequencies of adulterants and diluents detected in each mass category of cocaine specimens seized in Western Switzerland since 2006 (n = 7841 specimens).

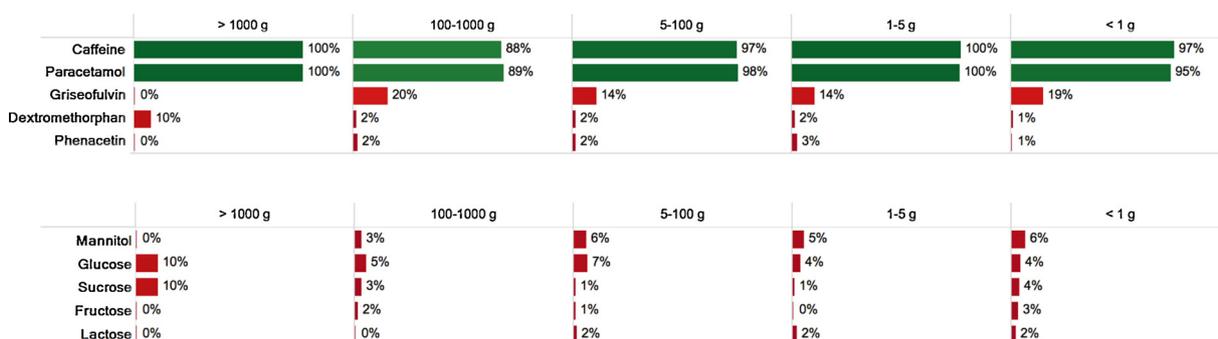


Fig. 7. Frequencies of adulterants and diluents detected in each mass category of heroin specimens seized in Western Switzerland since 2006 (n = 3476 specimens) (DXM = dextromethorphan).

Fig. 7 represents the frequency of adulterants (top) and diluents (bottom) for each mass category in heroin specimens. Adulteration was mainly restricted to a combination of two adulterants (caffeine and paracetamol) at all levels of the supply chain. Although rarer, griseofulvin (an anti-fungal medication) was also used, in particular for specimens weighing less than 1000 g. In regard to dilution, the figure confirms its limited occurrence at distribution, intermediate and consumption levels.

**General discussion and conclusions**

This article focused on the analysis of heroin and cocaine cutting agents to investigate when and how cutting occurs in Switzerland using the largest dataset ever reported. Although our data did not inform on the magnitude of adulteration/dilution at source level, it gave objective insights into the levels in the distribution at which cutting occurs once in Switzerland. In cocaine specimens, both adulteration and dilution were responsible for the purity decrease along the supply chain. In contrast, only adulteration was responsible for the purity decrease along the heroin supply chain which seems to occur at an upper or intermediate level in the supply chain. These observations are in line with the literature which reported that adulteration is decided at the production or just after importation (1999, Coomber & Maher, 2006; Coomber, 1997b). Nevertheless, our observations regarding the cutting

of heroin are different from older studies that observed little purity difference between the heroin seized by customs (i.e. prior to its distribution in the country of consumption) and heroin seized at the street level (i.e. end of the supply chain) (1999, Coomber, 1997c; de la Fuente, Saavedra, Barrio, Royuela, & Vicente, 1996; Kaa, 1994; King, 1997). Our results showed a decrease of nearly two-thirds in purity between specimens weighing more than 1000 g and specimens weighing less than 100 g. Interestingly, this purity decrease was due to one specific combination of adulterants – caffeine and paracetamol. In Switzerland, adulteration seems to occur at an intermediate level in the supply chain. This observation is supported by the analysis of seizures containing only cutting agents during the same timeframe (Broséus, Gentile et al., 2015). The mixture of caffeine and paracetamol (of brown colour similar to the majority of heroin seized in Switzerland) represents the most common combination of adulterants seized. Thus, there seems to be a trafficking of this particular combination of adulterants. This was further confirmed by interviews with informants, drug squad officers and investigators in Switzerland (Zobel et al., 2017). According to the interviews, this combination of adulterants is trafficked into Switzerland at the same time heroin is trafficked or in parallel to the heroin trafficking and by the same networks.

Similar to the study investigating the potential of chemical class for intelligence purposes (Broséus, Gentile et al., 2016), our research highlights a different dynamic in the respective markets. This difference

might be explained, among other factors, by the geographical location of the producing countries and the proximity of Switzerland to these producing countries. Indeed, most of the heroin found in Switzerland (and Europe) originates from Afghanistan and is imported into Switzerland through the Balkan route (United Nations Office on Drugs & Crime, 2016). Heroin supply routes in Switzerland are more limited and are mainly controlled by the Albanian-speaking crime groups (Guéniat & Esseiva, 2005; Zobel et al., 2017). Paoli & Reuter reported that Western Europe appears to be dominated by specific immigrant groups (Paoli & Reuter, 2008). Upper level trafficking of heroin is frequently associated with Turkish and Albanian groups (Wilson & Stevens, 2008). In contrast, cocaine is mainly produced in Peru, Colombia and Bolivia and shipped from different countries in North, South and Central America to Europe. As a consequence, due to the location where cocaine is produced, several distribution channels (e.g. air, cargo, train, road and use of different drug mules), supply routes and trafficking flows co-exist. Furthermore, it might pass through West Africa, a distribution channel that regained importance, before reaching Switzerland (United Nations Office on Drugs & Crime, 2016).

In conclusion, this research provides objective information regarding the cutting of cocaine and heroin within a destination country. Although heroin and cocaine markets in Switzerland might be different from other countries, this study highlights the adulterants worth targeting at the border but also the combination of adulterants that might be synthesised on a large-scale or trafficked into the destination country. This study also shows that chemical profiling based on adulterants and diluents has potential to complement the alkaloid profiles commonly used to reveal distribution networks. If such information was systematically collected and analysed by law enforcement agencies and laboratories, it would provide complementary and additional knowledge on the structure of drug markets and potentially reveal other actors involved in drug trafficking. In addition, the analysis of adulterants and diluents can be used to inform customs, law enforcement agencies, policy makers and laboratory personnel about legal substances commonly used to cut illicit drugs and diverted from the legal market. Better understanding the structure and operations of drug markets can assist law enforcement agencies choose where and when they should focus their activities (Wilson & Stevens, 2008). Finally, gaining knowledge about the type and concentration of cutting agents enables the development of sound strategies to reduce risk to public health and harms related to drug use. It provides a tool to monitor the composition of illicit drugs entering the market and identify potentially harmful substances which could be detrimental for consumers.

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## References

Andreasen, M. F., Lindholm, C., & Kaa, E. (2009). Adulterants and diluents in heroin, amphetamine, and cocaine found on the illicit drug market in Aarhus, Denmark. *The Open Forensic Science Journal*, 2, 16–20.

Broséus, J., Baechler, S., & Esseiva, P. (2017). A response to "The importance of economic context in interpreting forensic data on drug trafficking networks". *Forensic Science International*, 273, e22–e23. <https://doi.org/10.1016/j.forsciint.2017.01.018>.

Broséus, J., Baechler, S., Gentile, N., & Esseiva, P. (2016). Chemical profiling: A tool to decipher the structure and organisation of illicit drug markets: An 8-year study in Western Switzerland. *Forensic Science International*, 266, 18–28. <https://doi.org/10.1016/j.forsciint.2016.04.008>.

Broséus, J., Debrus, B., Delémont, O., Rudaz, S., & Esseiva, P. (2013). Study of common database feeding with results coming from different analytical methods in the framework of illicit drugs chemical profiling. *Forensic Science International*, 230(1–3), 16–28. <https://doi.org/10.1016/j.forsciint.2013.02.040>.

Broséus, J., Gentile, N., Bonadio Pont, F., Garcia Gongora, J. M., Gasté, L., & Esseiva, P. (2015). Qualitative, quantitative and temporal study of cutting agents for cocaine and heroin over 9 years. *Forensic Science International*, 257, 307–313. <https://doi.org/10.1016/j.forsciint.2015.09.014>.

Broséus, J., Gentile, N., & Esseiva, P. (2016). The cutting of cocaine and heroin: A critical review. *Forensic Science International*, 262, 73–83. <https://doi.org/10.1016/j.forsciint.2016.02.033>.

Broséus, J., Gentile, N., Gaste, L., Estoppey, N., Corazza, D., & Esseiva, P. (2015). Les produits de coupage de la cocaïne et de l'héroïne: partie 2. Une étude de la composition des saisies suisses. *Revue Internationale de Criminologie et de Police Technique et Scientifique*, LXVIII(1), 97–120.

Broséus, J., Huhtala, S., & Esseiva, P. (2015). First systematic chemical profiling of cocaine police seizures in Finland in the framework of an intelligence-led approach. *Forensic Science International*, 251, 87–94. <https://doi.org/10.1016/j.forsciint.2015.03.026>.

Brunt, T. M., Nagy, C., Bücheli, A., Martins, D., Ugarte, M., Beduwe, C., & Ventura Vilamala, M. (2017). Drug testing in Europe: Monitoring results of the Trans European Drug Information (TEDI) project. *Drug Testing and Analysis*, 9(2), 188–198. <https://doi.org/10.1002/dta.1954>.

Brunt, T. M., Rigter, S., Hoek, J., Vogels, N., Van Dijk, P., & Niesink, R. J. M. (2009). An analysis of cocaine powder in the Netherlands: Content and health hazards due to adulterants. *Addiction*, 104(5), 798–805. <https://doi.org/10.1111/j.1360-0443.2009.02532.x>.

Caulkins, J. P., & Reuter, P. (1998). What price data tell us about drug markets. *Journal of Drug Issues*, 28(3), 593–612.

Chaudron-Thozet, H., Girard, J., & David, J. J. (1992). Analysis of heroin seized in France. *Bulletin on Narcotics*, 44(1), 29–33.

Cole, C., Jones, L., McVeigh, J., Kicman, A., Syed, Q., & Bellis, M. (2010). A guide to adulterants, bulking agents and other contaminants found in illicit drugs. Retrieved from Liverpool: <https://www.cahma.org.au/Downloads/cut.pdf>.

Cole, C., Jones, L., McVeigh, J., Kicman, A., Syed, Q., & Bellis, M. (2011). Adulterants in illicit drugs: A review of empirical evidence. *Drug Testing and Analysis*, 3(2), 89–96. <https://doi.org/10.1002/dta.220>.

Coomber, R. (1997a). The adulteration of drugs: What dealers do to illicit drugs, and what they think is done to them. *Addiction Research*, 5(4), 297–306. <https://doi.org/10.3109/16066359709004344>.

Coomber, R. (1997b). Dangerous drug adulteration: An international survey of drug dealers using the Internet and the World Wide Web (WWW). *International Journal on Drug Policy*, 8(2), 71–81.

Coomber, R. (1997c). How often does the adulteration/dilution of heroin actually occur? *International Journal of Drug Policy*, 8(4), 178–186.

Coomber, R. (1999). The cutting of heroin in the United States in the 1990s. *Journal of Drug Issues*, 29(1), 17–36.

Coomber, R., & Maher, L. (2006). Street-level drug market activity in Sydney's primary heroin markets: Organization, adulteration practices, pricing, marketing and violence. *Journal of Drug Issues*, 36(3), 719–753.

de la Fuente, L., Saavedra, P., Barrio, G., Royuela, L., & Vicente, J. (1996). Temporal and geographic variations in the characteristics of heroin seized in Spain and their relation with the route of administration. *Drug and Alcohol Dependence*, 40(3), 185–194. [https://doi.org/10.1016/0376-8716\(95\)01208-7](https://doi.org/10.1016/0376-8716(95)01208-7).

Desroches, F. (2007). Research on upper level drug trafficking: A review. *Journal of Drug Issues*, 37(4), 827–844.

Dujourdy, L., Besacier, F., & Ladroue, V. (2010). La cocaïne saisie en France. Exploitation des données statistiques nationales. *Actualité chimique*, 342-343, 29–36.

Esseiva, P. (2004). *Le profilage de l'héroïne et de la cocaïne: mise en place d'une systématique permettant une utilisation opérationnelle des liens chimiques*. (PhD). Lausanne: Université de Lausanne.

Esseiva, P., Anglada, F., Dujourdy, L., Taroni, F., Margot, P., Pasquier, E. D., ... Doble, P. (2005). Chemical profiling and classification of illicit heroin by principal component analysis, calculation of inter sample correlation and artificial neural networks. *Talanta*, 67(2), 360–367. <https://doi.org/10.1016/j.talanta.2005.03.041>.

Esseiva, P., Dujourdy, L., Anglada, F., Taroni, F., & Margot, P. (2003). A methodology for illicit heroin seizures comparison in a drug intelligence perspective using large databases. *Forensic Science International*, 132(2), 139–152. [https://doi.org/10.1016/S0379-0738\(03\)00010-0](https://doi.org/10.1016/S0379-0738(03)00010-0).

Esseiva, P., Gaste, L., Alvarez, D., & Anglada, F. (2011). Illicit drug profiling, reflection on statistical comparisons. *Forensic Science International*, 207(1-3), 27–34. <https://doi.org/10.1016/j.forsciint.2010.08.015>.

Esseiva, P., Ioset, S., Anglada, F., Gasté, L., Ribaux, O., Margot, P., ... Ottinger, E. (2007). Forensic drug intelligence: An important tool in law enforcement. *Forensic Science International*, 167(2-3), 247–254. <https://doi.org/10.1016/j.forsciint.2006.06.032>.

European Monitoring Centre for Drugs and Drug Addiction-Europol (2010). *Cocaine: A European Union perspective in the global context*. Retrieved from Luxembourg: [http://www.emcdda.europa.eu/system/files/publications/554/TDAN09002ENC\\_204898.pdf](http://www.emcdda.europa.eu/system/files/publications/554/TDAN09002ENC_204898.pdf).

European Monitoring Centre for Drugs and Drug Addiction. Cocaine trafficking to Europe Retrieved from: [http://www.emcdda.europa.eu/system/files/publications/2702/Cocaine%20trafficking\\_POD2016.pdf](http://www.emcdda.europa.eu/system/files/publications/2702/Cocaine%20trafficking_POD2016.pdf), 2016a.

European Monitoring Centre for Drugs and Drug Addiction. European drug report 2016: Trends and developments Retrieved from Luxembourg: <http://www.emcdda.europa.eu/system/files/publications/2637/TDAT16001ENN.pdf>, 2016b.

Guéniat, O., & Esseiva, P. (2005). *Le profilage de l'héroïne et de la cocaïne. Une méthodologie moderne de lutte contre le trafic illicite*. Lausanne: Presses polytechniques et universitaires romandes.

Ioset, S., Esseiva, P., Ribaux, O., Weyermann, C., Anglada, F., Locicero, S., ... Margot, P. (2005). Establishment of an operational system for drug profiling: A Swiss experience. *Bulletin on Narcotics*, 57(1-2), 121–147.

Kaa, E. (1994). Impurities, adulterants and diluents of illicit heroin. Changes during a 12-year period. *Forensic Science International*, 64(2), 171–179. [https://doi.org/10.1016/0379-0738\(94\)90228-3](https://doi.org/10.1016/0379-0738(94)90228-3).

- Kilmer, B., & Hoorens, S. (2010). *Understanding illicit drug markets, supply-reduction efforts, and drug-related crime in the European Union* Retrieved from Santa Monica: [https://www.rand.org/content/dam/rand/pubs/technical\\_reports/2010/RAND\\_TR755.sum.pdf](https://www.rand.org/content/dam/rand/pubs/technical_reports/2010/RAND_TR755.sum.pdf).
- King, L. A. (1997). Drug content of powders and other illicit preparations in the UK. *Forensic Science International*, 85(2), 135–147. [https://doi.org/10.1016/S0379-0738\(96\)02089-0](https://doi.org/10.1016/S0379-0738(96)02089-0).
- Kudlacek, O., Hofmaier, T., Luf, A., Mayer, F. P., Stockner, T., Nagy, C., ... Sitte, H. H. (2017). Cocaine adulteration. *Journal of Chemical Neuroanatomy*, 83–84, 75–81. <https://doi.org/10.1016/j.jchemneu.2017.06.001>.
- Lahaie, E. (2012). Quel est le produit qui circule? In M. Pousset (Ed.). *Cocaïne, données essentielles*. Saint-Denis, France: OFDT.
- Maietti, S., Castagna, F., Molin, L., Ferrara, S. D., & Traldi, P. (2009). Cocaine adulterants used as marker compounds. *Journal of Mass Spectrometry*, 44(7), 1124–1126. <https://doi.org/10.1002/jms.1578>.
- Morelato, M., Baechler, S., Ribaux, O., Beavis, A., Tahtouh, M., Kirkbride, P., ... Margot, P. (2014). Forensic intelligence framework—Part I: Induction of a transversal model by comparing illicit drugs and false identity documents monitoring. *Forensic Science International*, 236, 181–190. <https://doi.org/10.1016/j.forsciint.2013.12.045>.
- Morelato, M., Beavis, A., Tahtouh, M., Ribaux, O., Kirkbride, P., & Roux, C. (2013). The use of forensic case data in intelligence-led policing: The example of drug profiling. *Forensic Science International*, 226(1–3), 1–9. <https://doi.org/10.1016/j.forsciint.2013.01.003>.
- Paoli, L., & Reuter, P. (2008). Drug trafficking and ethnic minorities in Western Europe. *European Journal of Criminology*, 5(1), 13–37. <https://doi.org/10.1177/1477370807084223>.
- Ribaux, O., Crispino, F., & Roux, C. (2014). Forensic intelligence: Deregulation or return to the roots of forensic science? *The Australian Journal of Forensic Sciences*, 1–11. <https://doi.org/10.1080/00450618.2014.906656>.
- Schneider, S., & Meys, F. (2011). Analysis of illicit cocaine and heroin samples seized in Luxembourg from 2005–2010. *Forensic Science International*, 212(1–3), 242–246. <https://doi.org/10.1016/j.forsciint.2011.06.027>.
- Stambouli, H., & El Bouri, A. (2017). Chemical profile of cocaine seizures and its adulterants in Morocco. *Forensic Science & Addiction Research*, 1(4), 1–4.
- United Nations (2001). *Drug characterization/impurity profiling background and concepts*. Retrieved from New York: <https://www.unodc.org/pdf/publications/st-nar-32-rev1.pdf>.
- United Nations Office on Drugs and Crime (2009). *World drug report 2009* Retrieved from New York: [https://www.unodc.org/documents/wdr/WDR\\_2009/WDR2009\\_eng\\_web.pdf](https://www.unodc.org/documents/wdr/WDR_2009/WDR2009_eng_web.pdf).
- United Nations office on Drugs and Crime (2010). *The globalization of crime: A transnational organized crime threat assessment* Retrieved from Vienna: [https://www.unodc.org/res/cld/bibliography/the-globalization-of-crime-a-transnational-organized-crime-threat-assessment\\_html/TOCTA\\_Report\\_2010\\_low\\_res.pdf](https://www.unodc.org/res/cld/bibliography/the-globalization-of-crime-a-transnational-organized-crime-threat-assessment_html/TOCTA_Report_2010_low_res.pdf).
- United Nations Office on Drugs and Crime (2014). *The illicit drug trade through south-eastern Europe* Retrieved from [https://www.unodc.org/documents/data-and-analysis/Studies/Illicit\\_DT\\_through\\_SEE\\_REPORT\\_2014\\_web.pdf](https://www.unodc.org/documents/data-and-analysis/Studies/Illicit_DT_through_SEE_REPORT_2014_web.pdf).
- United Nations Office on Drugs and Crime (2016). *World drug report 2016* Retrieved from New York: [https://www.unodc.org/doc/wdr2016/WORLD\\_DRUG\\_REPORT\\_2016\\_web.pdf](https://www.unodc.org/doc/wdr2016/WORLD_DRUG_REPORT_2016_web.pdf).
- Wilson, L., & Stevens, A. (2008). *Understanding drug markets and how to influence them* Retrieved from Oxford: [https://beckleyfoundation.org/wp-content/uploads/2016/04/BF\\_Report\\_14.pdf](https://beckleyfoundation.org/wp-content/uploads/2016/04/BF_Report_14.pdf).
- Zhilla, F., & Lamallari, B. (2015). *Organized crime threat assessment in Albania*. Retrieved from Tirana: [https://globalinitiative.net/wp-content/uploads/2018/02/Threat\\_Assessment\\_of\\_Albanian\\_Organised.pdf](https://globalinitiative.net/wp-content/uploads/2018/02/Threat_Assessment_of_Albanian_Organised.pdf).
- Zobel, F., Esseiva, P., Udrisard, R., Lociciro, S., & Samitca, S. (2017). *Le marché des stupéfiants dans le canton de Vaud: Les opioïdes*. Retrieved from Lausanne: [http://www.addictionsuisse.ch/fileadmin/user\\_upload/Rapport\\_MARSTUP\\_1.pdf](http://www.addictionsuisse.ch/fileadmin/user_upload/Rapport_MARSTUP_1.pdf).
- Zobel, F., Esseiva, P., Udrisard, R., Lociciro, S., & Samitca, S. (2018). *Le marché des stupéfiants dans le canton de Vaud. Partie 2: Cocaïne et autres stimulants*. Retrieved from Lausanne: [http://www.addictionsuisse.ch/fileadmin/user\\_upload/DocUpload/Marstup\\_2\\_Stimulants\\_Rapport\\_final.pdf](http://www.addictionsuisse.ch/fileadmin/user_upload/DocUpload/Marstup_2_Stimulants_Rapport_final.pdf).