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Changes in drug use in European cities during early COVID-19 lockdowns – A snapshot from wastewater analysis

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ABSTRACT

The COVID-19 outbreak has forced countries to introduce severe restrictive measures to contain its spread. In particular, physical distancing and restriction of movement have had important consequences on human behaviour and potentially also on illicit drug use and supply. These changes can be associated with additional risks for users, in particular due to reduced access to prevention and harm reduction activities. Furthermore, there have been limitations in the amount of data about drug use which can be collected due to restrictions. To goal of this study was to obtain information about potential changes in illicit drug use impacted by COVID-19 restrictions. Wastewater samples were collected in seven cities in the Netherlands, Belgium, Spain and Italy at the beginning of lockdowns (March-May 2020). Using previously established and validated methods, levels of amphetamine (AMP), methamphetamine (METH), MDMA, benzoylecgonine (BE, the main metabolite of cocaine) and 11-nor-9-carboxy-Δ^9-tetrahydrocannabinol (THC-COOH, main metabolite of tetrahydrocannabinol (THC)) were measured and compared with findings from previous years. Important differences in levels of consumed drugs were observed across the considered countries. Whilst for some substances and locations, marked decreases in consumption could be observed (e.g., 50% decrease in MDMA levels compared to previous years). In some cases, similar or even higher levels compared to previous years could be found. Changes in weekly patterns were also observed, however these were not clearly defined for all locations and/or substances. Findings confirm that the current situation is highly heterogeneous and that it remains very difficult to explain and/or predict the effect that the present pandemic has on illicit drug use and availability. However, given the current difficulty in obtaining data due to restrictions, wastewater analysis can provide relevant information about the situation at the local level, which would be hard to obtain otherwise.

1. Introduction

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) outbreak forced countries to introduce various measures to constrain its spreading. Home confinement, physical distancing and closing of non-essential activities, have had profound effects on individuals and

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societies. These changes have also affected substance use and associated risks due to reduced supplies, limited prevention, treatment and harm reduction activities (EMCDDA 2020a; 2020b; Dietze and Peacock 2020). These changes triggered the implementation of innovative methods to assess the impact lockdowns have on substance use and drug markets. In particular, mixed-method trend-spotter studies were introduced by the European Centre for Drugs and Drug Addiction (EMCDDA) to assess the situation (EMCDDA 2020b). These studies illustrate the complex and heterogeneous situation of drug use and markets in Europe during the early stages of the pandemic and highlighted the need for additional and localized surveys. In fact, due to differences in severity and timing of measures introduced in different countries, it remains difficult to explain and predict the effect that these will have on substance use and availability (Giommoni 2020; EMCDDA and Europol 2020). While there appears to have been a decrease in stimulants consumption across Europe, in particular cocaine and MDMA, changes are not homogeneously distributed across the continent (EMCDDA 2020b). An increased use of amphetamine in Nordic cities has been reported, whereas changes in cannabis use were more variable (Finnish Institute for Health and Welfare 2020; EMCDDA 2020b). Specifically, a decrease or cessation was reported among occasional users in southern Europe, while the opposite was found among frequent users in northern Europe (EMCDDA 2020b).

A complementary approach which could help gather additional information in these complex circumstances is wastewater-based epidemiology (WBE). While it cannot provide information about changes at the individual level (e.g., users switching to more harmful substances/administration routes), it can detect community-wide modifications in substance use, potentially symptomatic of changes in user behaviour or supply. Given the current circumstances, in which contacts with users are limited due to lockdown and social distancing measures (e.g., limited access to drug-related health services), WBE is a valuable source of complementary information. This has recently been shown also by Reinstadler et al. (2019), who used WBE to assess changes in illicit drug, alcohol and pharmaceutical use in the city of Innsbruck (Austria) between March and April 2020. The authors showed that changes in mass loads of illicit drugs and alcohol could be observed when compared to data from previous years.

The goal of this study was to apply WBE in order to evaluate spatial and temporal changes in illicit drug use in selected communities in the Netherlands, Belgium, Spain and Italy, during the early phase of the pandemic. Following standardized sampling protocols and validated analytical methods, levels of cocaine (COC) and its main metabolite benzoylecgonine (BE), amphetamine (AMP), 3,4-methylenedioxymethamphetamine (MDMA), methamphetamine (METH) and cannabis, through measurement of 11-nor-9-carboxy-Δ^9-tetrahydrocannabinol (THC-COOH), were determined in wastewater samples collected from 7 locations between March and May 2020. Findings were then compared to results from previous monitoring campaigns, which have been carried out yearly since 2011.

2. Methods

2.1. Wastewater sampling

Influent wastewater samples were collected between March and May 2020 at the entrance of the wastewater treatment plants (WWTPs) of the 7 cities mentioned in Table 1. All samples were 24-hour composite samples, collected following the protocols established in the yearly monitoring campaigns coordinated by the Sewage Analysis Core group Europe (SCORE) (González-Mariño et al., 2020; Castiglioni et al. 2013; SCORE 2020). Historic data consists of results from yearly sampling campaigns, organized by SCORE between March and April since 2011 and published by the EMCDDA (EMCDDA, 2020c). Additional data such as population and wastewater flows were provided by the WWTPs personnel and were used to compute population normalized daily loads (expressed in milligrams of substance excreted per day per thousand inhabitants [mg/day.1000 inhabitants]).

Table 1
Locations, sampling dates, important containment measures and Government Response Stringency Index (GRSI) (University of Oxford 2020) of the sampling campaign.

Country	Location	Sampling period in 2020	Important dates	GRSI*
Netherlands	Amsterdam Utrecht Eindhoven	18.03.2020 24.03.2020	12 march 2020: First step into lockdown - work from home 15 March 2020: Step two - closing of all schools, restaurants, bars and nightclubs 23 March: Step three - contact professions (e.g., hairdressers) on-hold state of "Intelligent lockdown"	62.0–74.1
Belgium	Brussels Boom	22.04.2020 28.04.2020	12 March 2020: first lockdown (i.e. closing of all bars, restaurants and nightclubs). 17 March 2020: full lockdown (i.e., all non-essential activities) 20 March 2020: closing of borders for all non-essential travel	81.5
Italy	Milan	19.05.2020 26.05.2020	22 February 2020: quarantine in areas of Lombardy and Veneto 9 March 2020: introduction of nation-wide measures (e.g., closing of non-essential activities)	63.9
Spain	Castellon	26.03.2020 01.04.2020	29 March 2020: introduction of total lockdown (i.e., closing of all non-essential activities)	71.8–85.2

*Government Response Stringency Index (GRSI) range or value over the dates the samples were collected.

2.2. Chemical analyses

Analyses of COC, BE, AMP, MDMA, METH and THC-COOH were carried out using liquid chromatography coupled to tandem mass spectrometry (LC-MS/MS). Analyses were performed in different laboratories and all methods used (van Nuijs et al. 2018; Bijlsma et al. 2014; Van Nuijs et al. 2009; Emke et al. 2018), including those used for historic data (priori to 2020), have been fully validated and successfully passed yearly proficiency tests (van Nuijs et al. 2018). Despite the uncertainties related to the measurement of THC-COOH, long-term monitoring within the same catchment provides useful insights in cannabis consumption (Burgard et al. 2019). Hence, THC-COOH was determined in all locations, except in Milan, Brussels and Boom where no validated method was available for this metabolite. Historic data presented here can be retrieved from the EMCDDA (2020c) or can be found in the recent paper by González-Mariño et al. (2020).

2.3. Data analysis

Differences in population normalized loads of the measured illicit drugs were evaluated using the nonparametric Wilcoxon rank sum test,

because in most cases data was not normally distributed. One- or two-sided tests were used to determine whether mass loads were higher, lower or equal compared to previous years, respectively.

3. Results

3.1. Yearly trends

For comparison purposes, an overview of excreted mass loads of targeted drug residues measured in the period from 2015 to 2020 is shown in Fig. 1. A thorough evaluation of trends in illicit drug use measured through WBE has been recently reported by (González-Mariño et al., 2020). It should be noted that for the cities of Eindhoven and Utrecht, not all data are reported as disposals of synthesis waste in sewers were detected in some years. These events are characterised by extremely high and erratic concentrations of AMP, MDMA and METH, which cannot be explained by consumption only (Emke et al. 2018) and measured loads can thus not be used to evaluate trends. In the cities of Utrecht, Brussels and Boom, no decrease in AMP mass loads was observed in 2020 compared to 2019 (one-sided Wilcoxon rank sum test, p-value < 0.05). On the contrary, the increasing trend observed in the last three years appears to continue into 2020. This was not the case for Amsterdam, where a decrease of almost 50% in AMP was observed, comparable to mass loads measured back in 2017 (one-sided Wilcoxon rank sum test, p-value > 0.05). In Castellon and Milan, AMP was either not detected or only sporadically, hence no comparison can be made. With respect to BE, loads measured in Utrecht and Brussels appear to still increase in 2020 despite the introduction of measures. However, statistical testing showed no significant difference between 2020 and 2019 for both cities (one-sided Wilcoxon rank sum test, p-value > 0.05). In Milan, however, a significant increase in BE loads was observed in 2020 compared to 2019 (one-sided Wilcoxon rank sum test, p-value $= 0.001$). For all other cities, an overall decrease in BE loads could be observed in 2020. In particular, Amsterdam (one-sided Wilcoxon rank sum test, p-value $= 0.03$) and Castellon (one-sided Wilcoxon rank sum test, p-value $= 0.0003$) showed a decrease in BE loads compared to previous years of more than 20% and 60%, respectively.

In the case of MDMA, no significant change could be observed in Utrecht, Brussels, Boom and Castellon in 2020 compared to previous years (two-sided Wilcoxon rank sum test, p-value > 0.05). On the contrary, Amsterdam and Milan showed a significant decrease (one-sided Wilcoxon rank sum test, p-value < 0.05) of almost 50% on average. In all cities, METH loads showed a decrease in 2020 compared to previous years, except for Brussels, where no significant change could be

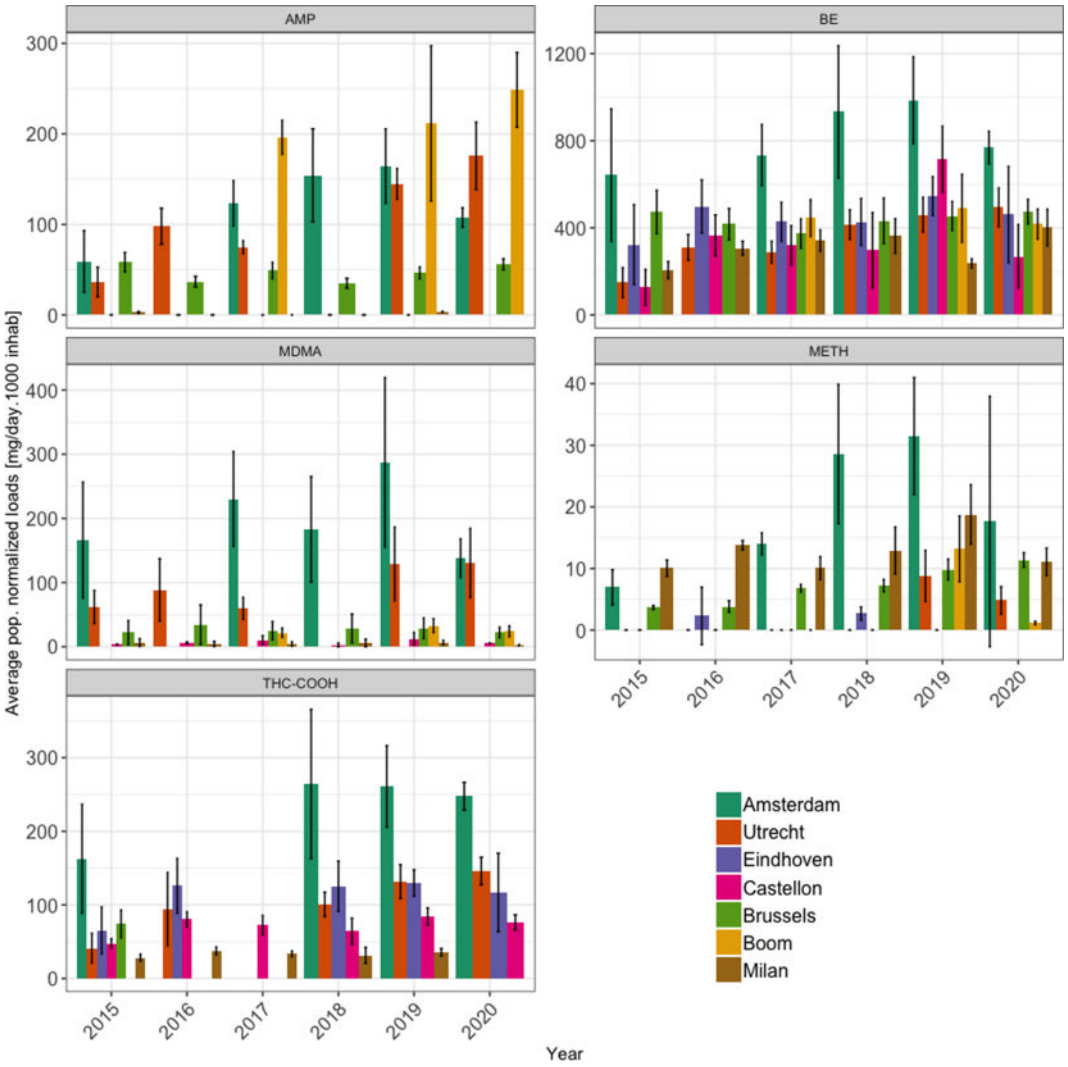

Fig. 1. 7-day yearly average and standard deviation of population normalized loads for AMP, BE, MDMA, METH and THC-COOH. Data for AMP and MDMA in Eindhoven was removed due to regular dumps of synthesis waste which does not reflect consumption. MDMA and AMP synthesis waste dumps were detected in 2018 in Utrecht and data is hence not shown here. Similarly, a dump of METH synthesis waste was detected in 2019 and 2020 in Eindhoven and hence removed. Data for Boom is available only for 2017, 2019 and 2020. THC-COOH was not monitored in Milan, Brussels and Boom.

observed (two-sided Wilcoxon rank sum test, p-value > 0.05). In Amsterdam, measured loads varied greatly, however a significant decrease could be observed between 2020 and 2019 (one-sided Wilcoxon rank sum test, p-value $= 0.01$). The other cities saw a decrease of 30% or more in METH loads in 2020 compared to 2019. Nevertheless, measured METH loads remain generally low in the monitored cities, hence these changes should be interpreted with caution.

THC-COOH was not monitored in all cities. In the case of Amsterdam and Castellon, a slight decrease in mass loads in 2020 compared to 2019 can be observed, however this was not statistically significant (one-sided Wilcoxon rank sum test, p-value > 0.05). Similarly, no significant difference was observed in Utrecht and Eindhoven in 2020 compared to 2019.

3.2. Weekly patterns

A comparison between weekly patterns in drug mass loads in the period 2018–2020 was performed to determine if any change in consumption patterns could be observed. A selection of the most relevant patterns is shown in Fig. 2. Weekly patterns of all substances and cities are reported in the Supporting Information (Tables S1-S4). No generalized change could be observed and weelky trends remained heterogeneous across cities. For instance, in Amsterdam, the weekend peak in AMP visible in 2018 and 2019 was absent in 2020, while in Brussels and Boom no particular change could be observed. In Milan, AMP was detected only in 2019, hence no comparison could be made. Similarly, in Castellon, AMP was not detected between 2018 and 2020. For BE, the weekend peak in Amsterdam was less pronounced compared to previous years, while in Utrecht, Brussels and Boom it remained unchanged. In Castellon, a steep decrease in BE loads from Thursday to Wednesday can be observed, while in 2019, there was a clear peak on Sunday. However, also in 2018, the weekend BE peak was not clearly defined, in particular because of another important peak on Wednesday. In the case of MDMA, the weekend peak was less pronounced in Amsterdam compared to previous years. Little to no change in the weekend pattern of MDMA was again observed in Utrecht, Brussels and Boom. In Milan, MDMA loads appear lower in 2020 compared to previous years. In particular, the weekend peak is almost one order of magnitude lower compared to 2018 and 2019.

In Castellon, an important difference in MDMA loads can be observed between 2020 and 2019. However, this is less obvious when compared to 2018 due to the low detection frequency. . In fact, in samples from 2020, MDMA was not detected between Monday and Wednesday. In the case of METH, observed weekly patterns differ greatly between cities.

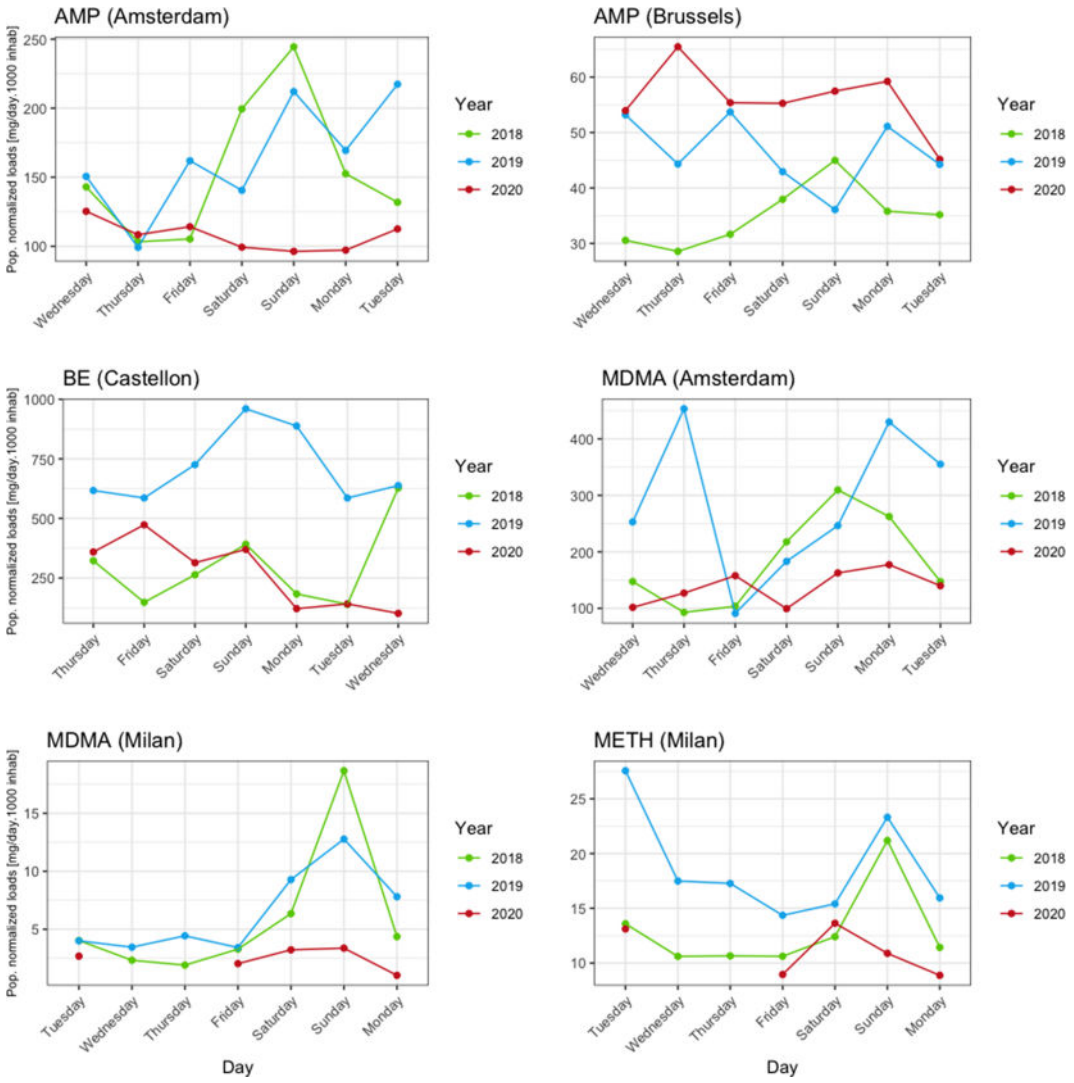

Fig. 2. Weekly patterns of illicit drug loads measured between 2018 and 2020 in a selection of cities. Weekly patterns for all substances and cities are reported in the Support Information. Each point represents an individual day. NB: The x-axis differs per city as samples were not collected on exactly the same days. In Milan, data from Wednesday and Thursday was not available in 2020.

For instance, in Milan, a peak was observed on Sundays, both in 2018 and 2019. Yet, in 2020 it appears to have decreased and shifted to Saturday. This also appears to be the case for Amsterdam. For THC-COOH, years differ greatly, and it is difficult to observe any specific change compared to previous years .

4. Discussion

The obtained data clearly highlights the heterogenic effect that restrictions have caused on illicit drug use. More so, speculations about a generalized decrease in consumption does not seem to have materialized. While in Amsterdam and Castellon, consumption of stimulants, such as COC, AMP and MDMA, has seen a substantial decrease in 2020, findings are more nuanced for Milan and, in particular, Utrecht. Depending on the substance considered, constant or even higher drug loads were observed in 2020 compared to previous years. Some hypotheses can be formulated to explain these observations, yet they remain speculative due to the complexity and short period considered. The important decrease in tourism and/or closing of nightlife could explain observations made in Amsterdam and Milan, for instance. Yet, diminished availability or changes in consumption patterns (Finnish Institute for Health and Welfare 2020; EMCDDA 2020b) or differences in severity of measures could also have an effect. In this sense, it is interesting to notice that, according to the Government Response Stringency Index (GRSI) (University of Oxford 2020), Spain (GRSI 71.8–85.2) had more stringent measures compared to the Netherlands (GRSI 62.0–74.1) (Table 1), yet the impact that these had on the situation of illicit drug use was not obvious. Both Amsterdam and Castellon saw a decrease in stimulant use, while Utrecht had a substantially different situation. Similarly, Belgium (GRSI 81.5) had comparable measures to Spain, yet the effect on illicit drug use appeared less pronounced, in particular for AMP and BE, which remained stable or even increased in 2020 in Brussels.

In the particular case of Milan, it should be noted that because of restrictions in place, sampling of wastewater took place only during the second half of May, which is later compared to the other cities considered here. Consequently, restrictions during this period were less stringent compared to the other cities considered here (i.e., GRSI in Italy during May was 64.9), which could explain why differences with previous years were less pronounced. These findings illustrate that it remains very difficult to attribute the observed changes to a single factor. With respect to synthesis of stimulants, results from Eindhoven, a renowned area for production, suggest that manufacturing of AMP, MDMA and METH in the area continued during the studied period. In fact, high loads, up to almost 350 mg/day 1000 inhabitants (or 1500 ng/L) of AMP were measured during weekdays. Similarly, loads of up to 92 mg/day 1000 inhabitants (or 340 ng/L) of METH were measured.

Weekly patterns were also very heterogeneous. For AMP, MDMA and BE weekend peaks were less pronounced or even completely absent in 2020. In Milan, a factor 10 difference in the amount of MDMA consumed during the weekend peak could be observed between the considered years. Interestingly, in Castellon, BE mass loads showed a steep decrease during the sampled week, which corresponded to the introduction of a full lockdown halting all non-essential activities. Finally, in Utrecht, weekly patterns of MDMA and BE still showed a clear trend, whereas the weekend peak was less pronounced in Amsterdam and Eindhoven, suggesting different dynamics in drug use.

For cannabis (measured through THC-COOH), weekly patterns were very heterogeneous across all years, making comparisons particularly challenging. Both yearly and weekly trends observed in the considered cities support the heterogeneous situation hypothesized by Giommoni et al. and the EMCDDA (Giommoni 2020; EMCDDA 2020b). This makes predictions about the effect that lockdown measures have on consumption very difficult, in particular due to national, regional and local characteristics, both in terms of drug use patterns as well as lockdown measures implemented and conformed by the public. Furthermore, given the continuously changing situation, with measures being introduced or relieved, results obtained here highlight the importance of having highly resolved, localized and multi-indicator monitoring campaigns.

5. Conclusion

The findings from this snapshot study show that the impact of the COVID-19 pandemic had heterogeneous effects on illicit drug use. In some of the studied locations, consumption remained stable or even increased compared to previous years, while clear reductions in drug use were seen elsewhere. Patterns of drug use also seem to have changed slightly, but these were both substance- and location-dependent. Results obtained here further highlight the complexity of the situation, which might increase further due to cyclic introduction and relieving of measures, and the importance of continuous monitoring using all multiple indicators. Nevertheless, at the local level, WBE can help partly disentangle this complex situation, in particular given the limited information which can currently be obtained directly from users. This will be relevant also for substances not included in this study, such as opioids, antidepressants and alcohol, whose consumption might have also changed during the COVID-19 pandemic (EMCDDA 2020b, Reinstadler et al., 2019).

CRediT authorship contribution statement

Frederic Been: Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing, Formal analysis, Visualization, Project administration, Funding acquisition. **Erik Emke:** Methodology, Investigation, Writing - original draft. **João Matias:** Data curation, Investigation, Writing - original draft. **Jose Antonio Baz-Lomba:** Data curation, Investigation, Writing - original draft. **Tim Boogaerts:** Data curation, Investigation, Writing - original draft, Writing - review & editing. **Sara Castiglioni:** Conceptualization, Methodology, Investigation, Writing - original draft, Funding acquisition. **Marina Campos-Mañas:** Data curation, Investigation, Writing - original draft. **Alberto Celma:** Data curation, Investigation, Writing - original draft. **Adrian Covaci:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing, Funding acquisition. **Pim de Voogt:** Conceptualization, Methodology, Writing - original draft, Funding acquisition. **Félix Hernández:** Conceptualization, Methodology, Writing - original draft, Funding acquisition. **Barbara Kasprzyk-Hordern:** Conceptualization, Methodology, Writing - original draft. **Thomas ter Laak:** Conceptualization, Methodology, Writing - original draft. **Malcolm Reid:** Conceptualization, Methodology, Writing - original draft, Data curation. **Noelia Salgueiro-González:** Data curation, Investigation, Writing - original draft. **Ruud Steenbeek:** Data curation, Investigation, Writing - original draft. **Alexander L.N. van Nuijs:** Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing, Funding acquisition. **Ettore Zuccato:** Conceptualization, Methodology, Writing - original draft, Funding acquisition. **Lubertus Bijlsma:** Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing, Formal analysis, Visualization, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envint.2021.106540.

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