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Trends and challenges in the use of drugs as forensic evidence: A scientometric approach to map the current literature

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Abstract

The rapid increase in the production and distribution of illicit drugs has led to vast amounts of data being generated through research and other publications, making it difficult to effectively distill and analyze current and emerging trends. The present study used a scientometric approach to identify trends and challenges in the use of drugs as an evidence type in forensic science by examining reference lists available in the INTERPOL IFSMS reports and the citation database Scopus. It has been identified that "new psychoactive substances" is one of the most frequently used keywords by authors, highlighting the swift response by communities to characterize these emerging compounds. However, it was also noted that despite drugs being a global threat, only limited international collaboration was observed between research groups and the majority of the studies are from authors affiliated within the same country. Finally, an argument is made to encourage a more comprehensive approach in aggregating results on drugs for greater transparency and broader distribution of findings.

This article is categorized under:

Forensic Chemistry > Mass Casualty Management

Forensic Chemistry > Controlled and Emerging Drug Compounds

KEYWORDS

collaborative network, drugs, INTERPOL, new psychoactive substances, Scopus

1 | INTRODUCTION

Access to previous studies is essential to developing a better understanding of an area of research, but also to identifying knowledge gaps. In forensic science, academic researchers can generally search and access publications using their institutions' subscriptions to citation databases (e.g., Scopus, Web of Science, etc.) but forensic practitioners may see a more limited range of materials if the published content is not freely accessible. To facilitate and share the latest advancements in forensic research, every 3 years the INTERPOL International Forensic Science Managers Symposium

(IFSMS) publishes a series of review papers that outline and summarize the major areas of interest to forensic science practitioners (INTERPOL). The IFSMS review includes many forensic evidence types with the topic of "drugs" being one core subject. However, the extensive content presented in the IFSMS reports remains challenging to process (Ménard et al., 2022).

In a forensic context, the word "drug" is a general term that covers a broad range of compounds which are illicitly imported, supplied and possessed. The United Nations Office on Drugs and Crime (UNODC) classifies drugs in six different categories: amphetamine-type stimulants, cocaine/coca, cannabis, hallucinogens, opiates, and sedative hypnotics ("United Nations Office on Drugs and Crime (UNODC)"). More recently, the production and use of synthetic drugs, also known as legal highs, designer drugs, novel/new psychoactive substances (NPS) or research chemicals have increased worldwide (BBC, 2014; Zapata et al., 2021). These drugs mainly fall under four common categories depending on their desired effects: (i) Synthetic cannabinoids, commonly known as "Spice" or "K2," aim to replicate the effects of Δ^9-tetrahydrocannabinol (Δ^9-THC), the main psychoactive component of cannabis; (ii) synthetic stimulants, including synthetic cathinones, intend to mimic the effects of drugs such as cocaine, ecstasy, or amphetamines; (iii) synthetic depressants are made to simulate the effects of tranquilizer drugs such as barbiturates (e.g., amobarbital, pentobarbital, etc.), benzodiazepines (e.g., alprazolam, diazepam, etc.) or prescription opioids (codeine, fentanyl, oxycodone, morphine, etc.); and (iv) synthetic hallucinogens are designed to mimic the effects of classic hallucinogens, such as lysergic acid diethylamide (LSD), and dissociative drugs, such as phencyclidine (PCP). Although they are designed to mimic traditional drugs, the chemical modifications of NPS have led to unintentional adverse effects, and even fatalities, which were not previously associated with the corresponding traditional drugs (Helander et al., 2020).

Up to the end of December 2021, 1124 NPSs have been reported by laboratories, institutions, and governments to the UNODC and the Early Warning Advisory (EWA), showing a significant increase from the 348 listed in 2013 and 166 in 2009 (BBC, 2014). The constant emergence of NPS has sparked extensive research, leading to a substantial volume of documents. However, the scale of information poses challenges to conventional methods of drug monitoring and surveillance, especially for forensic practitioners who require access to real-time information involved in drug-related cases.

One approach that has been developed to improve access to real-time information on newly emerging compounds, is the combination of lab-based observations with an online mass spectral database (HighResNPS) to obtain complementary information. Data stored in HighResNPS is kept up to date thanks to the contribution of many forensic laboratories around the world. While the content of HighResNPS currently only lists NPS found in drug seizures, new research by Skinnider et al. (2021) has been built on this collective database to help with the early identification of new compounds that are not yet included in any reference lists.

Another approach to monitoring large amounts of information is to visualize activity and trends using a scientometric approach. The use of scientometric analysis facilitates the establishing of research directions and their relationships such as who (authors), what (keywords), where (location), when (year), and with whom (affiliations). The use of scientometric analysis to measure progress in research is not novel and has started to emerge as one approach in forensic science (see, e.g., Ménard et al., 2022; Sobreira et al., 2020). However, such an approach has not yet been applied to drugs in a forensic context. This work aims at mapping the current information that is available in the literature in a systematic manner leading to bring further insights into how research developed over the years. Using the reference materials contained in the IFSMS reports, the citation database Scopus, and the HighResNPS database (Mardal et al., 2019), this work focuses on the geographical distribution of NPS and the extent of knowledge sharing and collaboration between institutions and countries.

2 | METHODOLOGY

2.1 | Publication lists

2.1.1 | INTERPOL IFSMS reviews

References were compiled from a reference list based on 10 (1991–2022) INTERPOL IFSMS triennial review papers focusing on the section titled "Drugs." The references listed in the IFSMS papers were searched using Scopus and exported using the CSV export function with all citation information: "Author(s)," "Author(s) ID," "Document title," "Year," "EID," "Source title," "Volume, issue, pages," "Citation count," "Source & document type," "Publication stage," "DOI" and "Open Access," as well as "Author keywords" and "Index keywords." The CSV exports were then compiled

into one reference list. Publications not found on Scopus were searched for in Google Scholar or an internet search browser. If no search results were obtained, the references were then added as entered in the IFSMS reports. These references were processed using a script written in the R statistical programming language and RStudio (open source) (Ménard et al., 2021). The code and the data are available via a persistent identifier at https://doi.org/10.5281/zenodo.8046815

2.1.2 | Citation database Scopus

Two search queries in the title, abstract and keyword were made on Scopus for all years (searches done in November 2022), the first one for "drugs" AND "Forensic" and the second for ((new OR novel) AND psychoactive AND substance) OR "Legal Highs" OR "Psychoactive substance." English terms were used for querying the citation databases and no attempt was made to exclude references written in another language. The output titles, abstracts, and authors' keywords were searched using the grep() function in R against the list of compounds extracted from the HighResNPS database (Mardal et al., 2019) (list of compounds exported as a table from the database in November 2022). grep() in R is a built-in function that searches for pattern matches within an element (see details at "grep in R: How to Use grep() Function in R," grep in R). This approach is different from text mining or the process for mining data based on text format. The R grep() function looks at matching patterns that exist in a character string and only minimum text cleaning is necessary (if required or wanted) before processing. Special characters such as brackets, commas, and dashes were removed from the reference list (i.e., the list generated from HighResNPS) and the searched text (Title, Abstract, and Keywords). Leading spaces and spaces as last characters were added to the reference lists to limit unwanted matches. For example, the term "MET" (i.e., with no added spaces) will return a positive match for "MET" but also for "METHAMPHETAMINE," "METHCATHINONE," "METHEDRONE," and so on, but only to "MET" if spaces before and after are included. In HighResNPS, "MET" appears in 373 terms without considering leading and trailing spaces and in 4 when they are included (i.e., 4-AcO-MET, 4-HO-MET, 5-MeO-MET, and MET). In such a case, if 4-AcO-MET, 4-HO-MET, or 5-MeO-MET are present in the searched text, an additional count for MET will occur. Within the Scopus reference content, only 4-HO-MET was found present on nine occurrences after text mining, leading to an overall increase of the total count for MET by 9, shared between five countries (Sweden [$n = 3$], Germany [$n = 2$], Switzerland [$n = 2$], China [$n = 1$], and South Korea [$n = 1$]). The inclusion of the hyphen instead of the space would encourage further distinction between terms but would require tailored corrections; for example, additional consideration between hyphen and dash both in the reference list and the text of interest. Knowing that the inclusion of spaces induces a small counting increase for some terms, no further correction was applied to keep data processing as simple as possible.

Countries were sorted by their highest overall number of matches to the reference list (HighResNPS) and the top 20 most frequently appearing entries were extracted. The final output data was compiled using the combined list of compounds (from all the countries) and the countries of interest.

2.2 | Keyword analysis

The keyword lists were generated from the authors' keywords which were checked for any spelling errors and word variation in the English language. A total of 4002 plausible corrections are available in the keyword correction list; a reference correction list built on previous works (Sobreira et al., 2020; Ménard et al., 2022). Abbreviations and acronyms were also standardized, including the names related to drugs which were harmonized using the lists provided by the U.S. Drug Enforcement Administration (DEA) (The U.S. Drug Enforcement Administration) and the UK Controlled drugs list (The UK Controlled Drugs List).

2.3 | Affiliations

Countries of origin were extracted from the reference lists using the authors' affiliations. Country duplicates were removed if more than one affiliation came from the same country. No attempt was made to analyze the data at institutional level.

3 | RESULTS AND DISCUSSION

The 10 most recent IFSMS reports (for the period 1991–2022) covering the evidence type "Drugs" contained 8750 references which were compiled. A total of 29,903 keywords were listed as authors' keywords, of which 12,235 were distinct (11,258 after applying keyword correction). Figure 1 shows the 101 keywords most frequently used by the authors of the 8750 references listed in the INTERPOL reports. The keywords seen in Figure 1 are mainly a mixture of drug compounds and instrumental techniques, as well as some more generic terms. Some of the keyword occurrences can be seen to vary significantly over time but none seem to have fallen out of favor.

The majority of techniques are found to appear in the early years reflecting the continuous use of standard techniques, such as GC–MS and FTIR. The first appearance of other techniques, such as tandem mass spectrometry in 2000, isotope ratio mass spectrometry in 2004, and high-resolution mass spectrometry in 2013, reflects the advancement in instrumental development and routine adoption of new techniques over time, with the latest analytical techniques becoming available to chemists who are interested in identifying new NPS. In the last four INTERPOL IFSMS reports, covering the years 2013–2022, the appearance of NPSs has received significant attention by the forensic drug community with NPS being the most frequently used keyword overall (52 times in 2017).

Searching the citation database Scopus with "drugs" AND "Forensic" returned 18,314 records for all years to the end of 2021. A total of 58,020 keywords were listed as authors' keywords, of which 22,229 were distinct (21,391 after correction). Figure 2 shows the 101 most frequently used keywords by the authors of the documents. Due to the search criteria, many of the keywords have a direct association with forensic, for example, Forensic Entomology, Medicine, Pathology, or Psychiatry to name just the top few. Nuclear Physics is also observed in the top keywords although not thought to be associated with the topic of interest. This illustrates how a general or simple search query in a citation database can lead to crossover with other research areas. Following the Scopus search query, no attempt was made to apply any exclusion on records that may not be suitable to the topic of interest, as it was applied for example in Galais et al. (2022). If selection criteria were to be applied, references associated with nuclear physics should be considered for exclusion.

Many of the authors' keywords listed in Figure 2 were also found in the INTERPOL reports (Figure 1), with 54 top keywords shared between them, and with relatively similar distribution. In the reference list from Scopus, "new psychoactive substances" is one of the most frequently used keywords, appearing 62 times in 2021 and 56 times in 2017, a similar count to what was observed in the INTERPOL reports, with only the terms "forensic science" and "forensic toxicology" having similar yearly counts. Finally, Figure 2 shows the emergence in research interest with a sudden increase in studies focusing on NPS, synthetic cathinone's and high-resolution mass spectrometry.

It is worth noting 14.9% (1497 out of 8750) of the references listed in the IFSMS reviews were found in the Scopus output, a percentage similar to what has been reported for other evidence types (i.e., Forensic Geoscience [14.2%], Paint and Glass [12.8%], Questioned documents [14.4%]) (Ménard et al., 2022). Even though the search on Scopus was never intended to match the reference list given by practitioners in the IFSMS reports, it still indicates some similarity between the two. It also demonstrates the importance of using multiple resources or search engines for a literature review as outputs can differ significantly between different resources.

In comparing the keyword lists generated from the INTERPOL reviews and Scopus search, it is clear that the INTERPOL reviews focus on drug analysis rather than toxicology and pathology. The reoccurring authors' keywords "toxicology" and "forensic toxicology" were found significantly more often in Scopus than the INTERPOL reviews with uses in 2.50% (457 uses) and 5.03% (921 uses) of references, respectively, in the Scopus reference list in comparison to 0.62% (54 uses) and 0.57% (50 uses) of references, respectively, in the INTERPOL reviews. In addition, in the INTERPOL reviews most prevalent keywords, multiple keywords related to drug profiling appear, including "drug profiling," "impurity profiling," "adulterant," "impurities," and "adulteration."

Drug profiling involves extracting information from a drug sample, including any adulterants, impurities, precursors, etc., to try to elucidate the synthetic pathway or connect a drug sample to a geographic origin or other drug seizures to aid in the elucidation of possible dealer-user networks (Ahmed et al., 2022). These drug profiling keywords are not present in the most common authors' keywords from the Scopus reference list which may indicate a greater interest in drug profiling by forensic practitioners than the research community. It is important to note that drug profiling is most useful for criminal investigations, a core focus of INTERPOL, who aim to reduce the trafficking of illicit substances. Drug profiling examination results may not be able to be published in the academic literature due to confidentiality requirements for legal cases, and obtaining samples for research purposes may be challenging, reducing research outputs in this area. Finally, it is also possible that the majority of research in the domain is on developing a better understanding of new drugs rather than developing intelligence, such as profiling or network analysis.

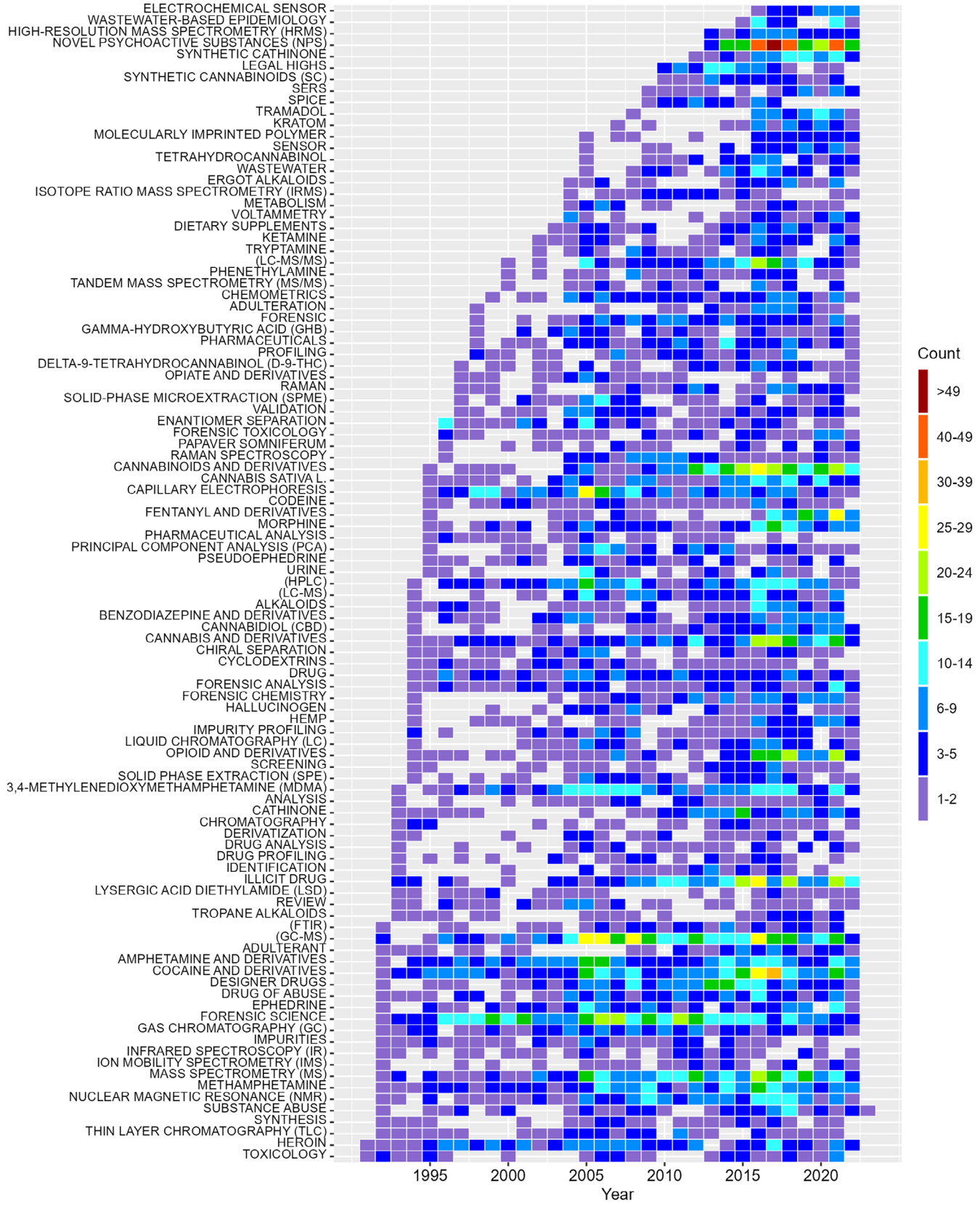

FIGURE 1 Most commonly found keywords in the 10 most recent INTERPOL reports covering the years 1991–2022. List ordered by year of first appearance. Frequency of use of the terms is included in the Figure S1.

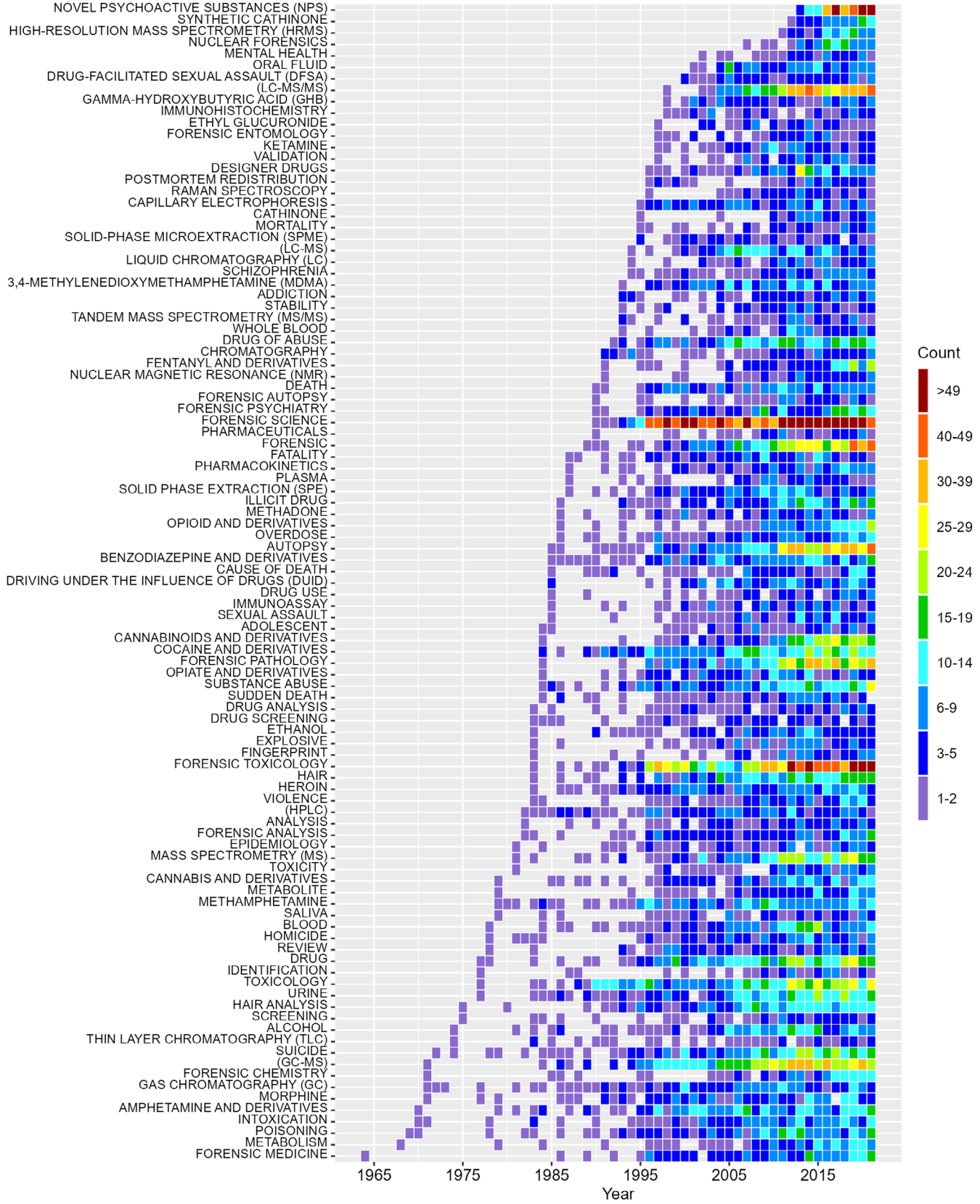

FIGURE 2 Most common authors' keywords listed in the reference list generated from the citation database Scopus. List ordered by year of first appearance. Frequency of use of the terms is included in the Figure S2.

Despite legislation being a main driver for change in the illicit drugs market, terms related to the legal system are seldom reported as keywords. "Law," "law enforcement," and "legislation" appeared a total of 20 times in the reference list given in the INTERPOL reviews, while these keywords were used 45 times in the Scopus search output. "Jurisprudence" and "legislation and jurisprudence" also only appeared 11 times in the reference list generated following the Scopus search. This does not imply there is a lack of published works related to jurisprudence, as it could be that this is simply not captured in the keywords selected by the authors as seen for example references (Andrews et al., 2022; Banister & Connor, 2018; Corkery et al., 2017; Norman et al., 2021). The paucity of legal terms observed suggests a lack of crossover between science and law and that the preferred keyword terminology employed by one research community (i.e., forensic science community) is not used by the other (i.e., jurisprudence). However, it is also possible that both reference lists (generated from the IFSMS reports and by querying Scopus) have a stronger representation in science than in social science, arts, and humanities despite Scopus being a multidisciplinary bibliographic database. Such observation is supported by the fact that the contents of the IFSMS reviews are mainly intended for a scientific audience for reporting on the latest discoveries and advancements. Finally, as with drug profiling, it may be that this work cannot be published in a timely manner due to ongoing legal proceedings.

The Scopus search for ((new OR novel) AND psychoactive AND substance) OR "Legal Highs" OR "Psychoactive substance" generated 8374 entries. The country of origin of the outputs was extracted from the authors' affiliations, and the results are shown in Figure 3. The United States had the largest paper count, followed by the United Kingdom and Italy. The content of the 8374 outputs was further analyzed by searching the records (Title, Abstract, and Keywords (Authors)) against NPS compounds listed in the HighResNPS database. A total of 7187 of the 8374 outputs generated by Scopus were found to have one or more positive matches to 730 of the 2240 compounds generated from HighResNPS.

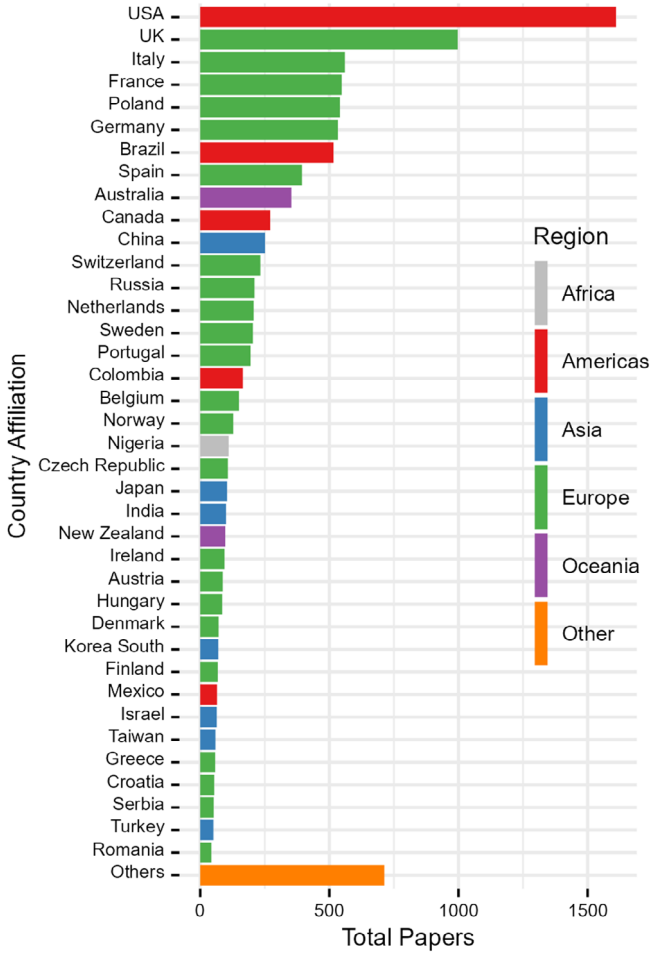

FIGURE 3 Country contribution found for NPS on Scopus. The countries are color-coded per geographical region. For outputs with authors from more than one country, a count was attributed to each individual country listed. Countries with less than 41 papers were collated in the "Others" category ($n = 88$).

Using the affiliation details available within the Scopus output data, a relationship between the listed compounds in the HighResNPS database and the research location can be established. The most frequently used terms (listed on HighResNPS) for all countries having three or more distinct matches to the reference list are shown in Figure 4. A threshold of three distinct compounds was set in the software code to include sufficient countries but also attempt to alleviate the large difference in the number of outputs per country. Figure 4 was generated by querying the data for the top three compounds most frequently reported for each country, as well as the inclusion of other compounds that matched the top lists of other countries. In simple terms, the top 3 most frequently cited compounds per country are combined together into a focused list which is then used to search against the original dataset. There are 119 compounds seen in Figure 4, with many commonly appearing between the 71 countries identified using the document affiliations. For example, 13 compounds listed in the HighResNPS database are found cited in the 19 countries (New Zealand to the United States) with the most matches to the database: amphetamine, buprenorphine, cathinone, cocaine, codeine, diazepam, fentanyl, ketamine, LSD, MDMA, MDPV (except New Zealand), mephedrone, MET (except Denmark), methamphetamine, methylone, morphine, and tramadol (except Canada). Methylphenidate, 1-pentylindole, and JWH-018 are also highly researched in all 19 top countries but are overtaken by methcathinone and alprazolam in the ranking as these two are researched across more countries. Benzoylecgonine is also seen being frequently reported in studies, but it is important to note that this is the major metabolite of cocaine and not a drug that is consumed (Hippenstiel & Gerson, 1994), so is likely connected to studies about cocaine.

While there are many similarities between the countries that largely report results towards a core group of compounds, there are also some noticeable differences and points of interest. Singapore and the United Arab Emirates are seen to have no data on compounds that were seen to be more commonly reported elsewhere. Singapore (17 compounds in total) reported on cocaine, cathinone, diazepam and LSD, and the United Arab Emirates (12 compounds in total) researched mephedrone, methylone, and diazepam. Another point of interest is that while in general the most frequently researched compounds for a country tend to be clustered towards a core group of traditional drugs of abuse (i.e., cocaine, amphetamine, methamphetamine, etc.), it is also seen that some countries focused on others. In their top three, the Netherlands reported 24 publications on 4-fluoroamphetamine, New Zealand reported benzylpiperazine (BZP) (6 counts), Finland reported buprenorphine (7 counts), and Malaysia reported mitragynine (5 counts). The higher rates of publication all highlight drugs of particular concern in the respective countries, see for example, references Ahmad and Aziz (2012); Kerr and Davis (2011); Kriikku et al. (2018); and Linsen et al. (2015) for these four countries.

Authors reporting on specific substances may be due to the prevalence of these compounds within their countries or for academic interest. With no terms or keywords agreed upon in the drug analysis community to help "classify" published research, the simple text search presented in this work to match the content of a reference list does not allow a distinction to be made between the two. The list of 8374 entries generated following the search on Scopus could be narrowed down by using keywords such as "seized," "seizure," "prevalence," or "case study," but care should always be taken to avoid being too restrictive and it is always best to read the abstract of documents to check their content. Within this list of 8374 entries, several studies were found to have an emphasis on reporting results from case studies.

da Cunha et al. reported on the prevalence of NPSs in Brazil following sample collections at 13 electronic dance music events from September 2018 to January 2020 (da Cunha et al., 2021). MDMA, ketamine, methylone, *N*-ethylpentylone were the most detected psychoactive substances. While the names of all four drug compounds were successfully extracted during text matching with the reference list, only MDMA appeared in the top three substances that were most commonly listed in the title, abstract, and keywords of documents affiliated with Brazil. (While not considered here, it should be noted all the authors except one are from Brazil, affecting the count for the United States as well.) The detection of NPS and other stimulant compounds is unsurprising, with these substances commonly reported in similar settings (see, e.g., Mohr et al., 2018). As well as reporting on MDMA, ketamine, methylone, and *N*-ethylpentylone, da Cunha et al. listed a further 38 substances in their manuscript that were not reported in the title, abstract, or keywords. This is a significant number but does not contribute and/or expand the overall list of 105 compounds found in the 515 documents affiliated with Brazil. This demonstrates a clear limitation of applying text matching over specific fields such as the title, abstract, and keywords of documents. Extracting details from full text is possible assuming the manuscripts are available, and this should also include Data S1 as the detail of the 42 substances reported by da Cunha et al. is also listed there. This would also address the issue of listed records that do not fall within the format of having an abstract or keywords.

For example, this is the case for the study reported by Richeval et al. on the prevalence of NPS from samples collected from French drivers (Richeval et al., 2021). The document, being a Letter to the Editors, does not contain an abstract or a list of keywords that can be searched against the content of a reference list of compounds. In their work, Richeval et al. reported the presence of 13 substances: ethylone, methylone, methylenedioxypyrovalerone, 4-methyl-*n*-ethylpentylone,

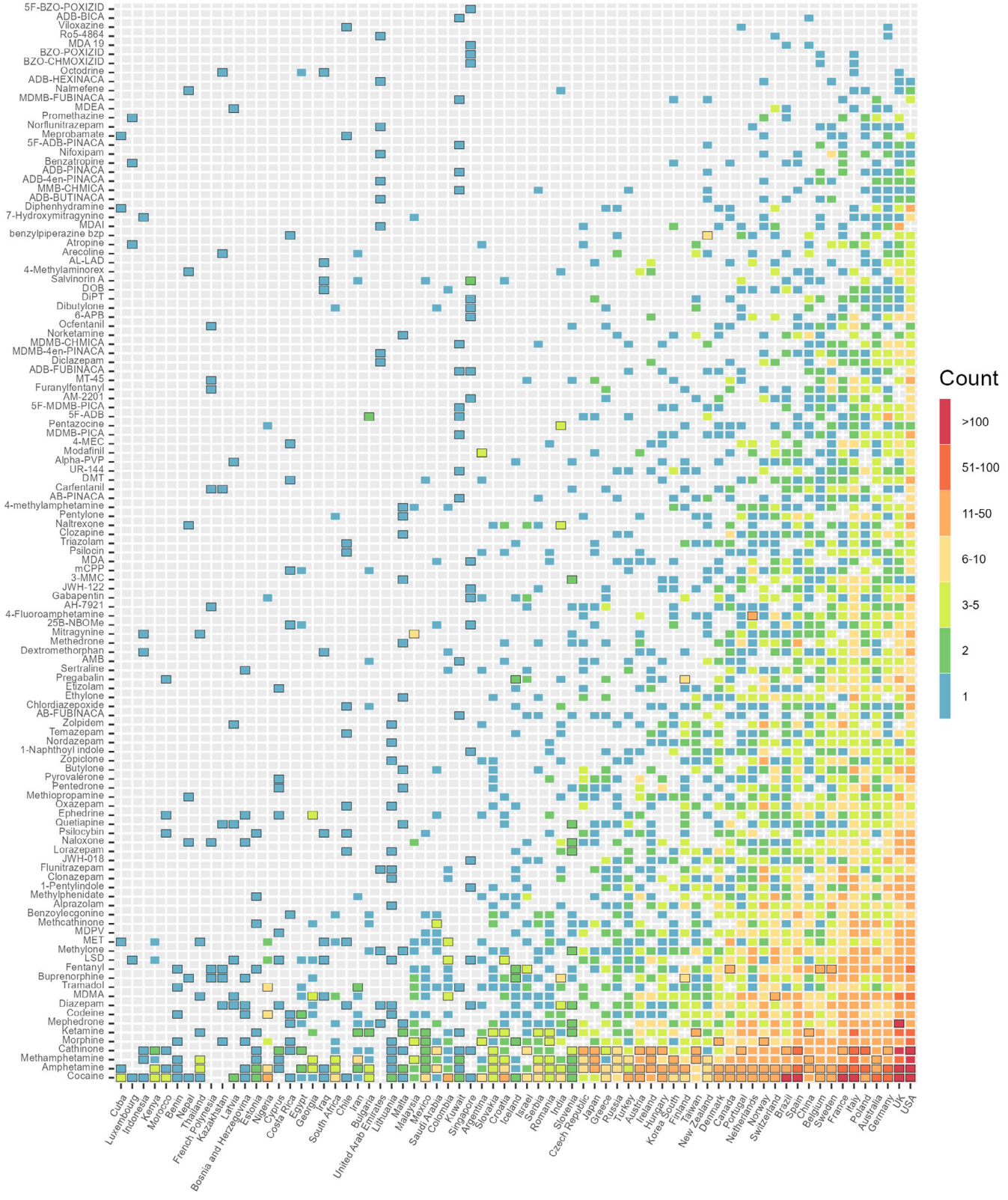

FIGURE 4 A total of 119 most common drug compounds listed in the HighResNPS database for the 71 countries with the highest number of matching entries. Drug compounds ordered according to their cumulative distinct frequencies across countries. Black boxes indicate the top (three or more) most frequently listed compounds for that country. Combined top three matching entries per country and matches against the entire dataset.

methamnetamine, LSD, methoxetamine, benzoylfentanyl, isopropylphenidate, ethylphenidate, 3-methylmethcathinone, X-chloromethcathinone, and 3-fluorophenmetrazine, which do not participate in the total counting for France in Figure 4. Performing a search on the full text returned a list of 14 substances, most of them given by Richeval et al., but missing X-chloromethcathinone and benzoylfentanyl while also including amphetamine, cathinone, and cocaine. As explained in the methodology regarding the text comparison approach used here, cathinone is found in 3-methylmethcathinone and X-chloromethcathinone, but it also appears on its own in the main text. Amphetamine and cocaine are also cited on their own in the introductory part of the work.

This discrepancy in the results is largely driven by the content of the reference list and how extensive it is. In the previous case of the work by Richeval et al. (2021), benzoylfentanyl is not listed in the reference list compiled from the HighResNPS database but *o*-methyl-benzoylfentanyl is. The same also applies for X-chloromethcathinone which only appears as 3-chloromethcathinone or 4-chloromethcathinone in the reference list. Under such conditions, it is not surprising that new NPS or not yet reported compounds in the HighResNPS database will be missed, regardless of whether the work focused on part of the document such as the title, abstract, and/or keywords, or on the full text. Text matching the full text also unavoidably includes substances that are not the main interest of the work but added by authors to provide context and comparison to the reader. It is also important to remember that processing entire documents would be a computer intensive task and prior to this would require significant manpower to collect all the documents even though the majority of them could be obtained using their digital object identifier (DOI).

With the increasing number of NPS reported by laboratories, institutions, and governments to the UNODC EWA, it also becomes important that information on existing and new compounds are reported and shared effectively within the research community. Part of this can be achieved through collaboration. The cooperative networks for the list of 8374 references generated by the Scopus search on NPS are shown in Figure 5. In this network visualization, in the absence of a database listing the geographic coordinate of every institution, the affiliations available in the documents were used to extract cities and countries which were associated with their geo-locations. Adopting this approach, it is acknowledged that the level of collaboration information at the national level may be limited, especially in situations where multiple affiliations exist within the same institution or between institutions located in the same city. In Figure 5, two major network triangles are observed between regions or countries: North America–Brazil–Europe and North America–Europe–Oceania. However, even though this demonstrates international collaboration, the data also show that the majority of partnerships still largely occur within each country (with co-authorship from different

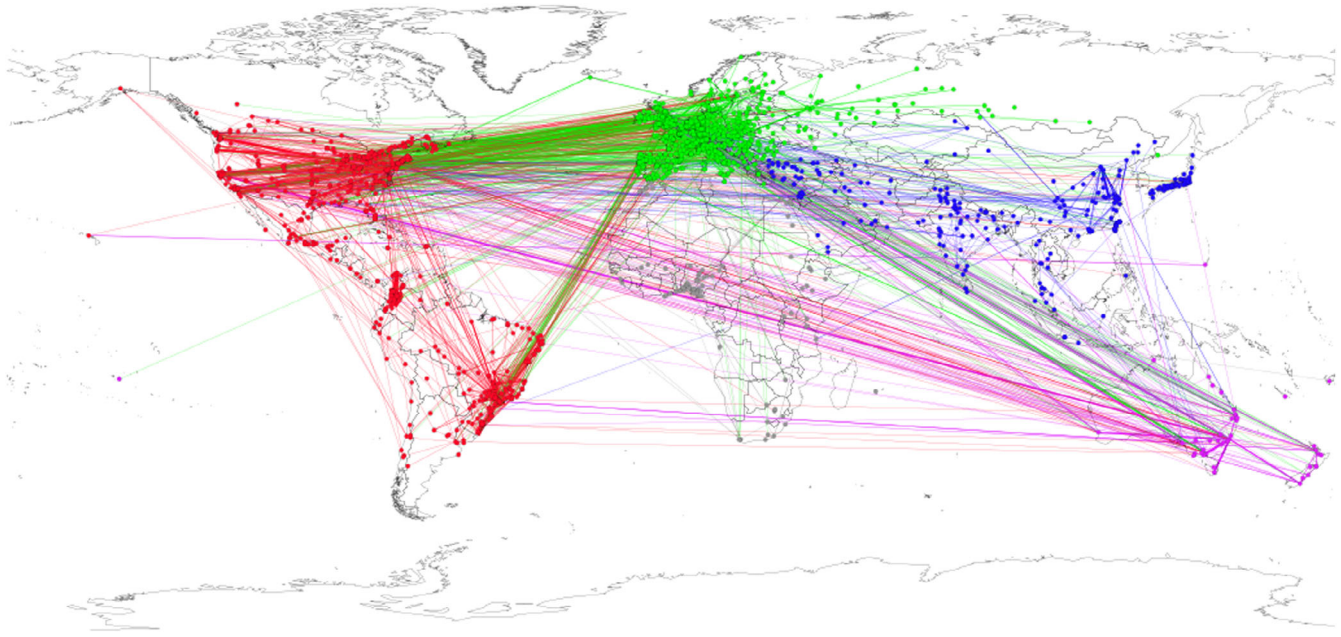

FIGURE 5 Network map for the 8374 outputs generated from Scopus for the search of NPS. The geolocation of the institutions only associated with their respective cities and countries. Institutions without reported collaboration excluded. Nodes colored by region. Edges (lines) colored according to the affiliation of the first listed author. Figure generated using the open source software Gephi (Bastian et al., 2009).

institutions and cities). Indeed, out of the 8374 records, 6689 (79.9%) are from authors affiliated within the same country, of which 2687 (32.1% out of 8374) are from articles with all authors based within the same institution.

Interestingly, the percentage of outputs with international collaboration is found to vary greatly between countries (Figure 6), from more than 60% for Ireland and Belgium to less than 10% for Poland and Japan, despite the commonality in the terms (i.e., drug compounds) used in the literature between countries, as presented in Figure 4. Variations in the level of international collaboration have been previously reported between disciplines (Winkler et al., 2015) but there is a paucity of data when comparing nations on a specific subject area. Nonetheless, in comparison to values reported across other science and engineering fields ("Science & Engineering Indicators," 2022), most countries demonstrate a greater level of international collaboration within the NPS field, although some of the nations are well below these values ("Science & Engineering Indicators," 2022), as shown in Figure 6. At this stage, it is unclear why there is such a disparity between nations and a more advanced network analysis would be required for any attempt to answer this question.

International collaboration is generally seen as an effective way to promote, share, and exchange knowledge, and this is further encouraged by the fact that it has never been that easy to connect with colleagues in other countries. Collaborating with one another offers many benefits such as, for example, learning new techniques and protocols, greater research capacity, better research visibility, or offering new opportunities to junior researchers (Francisco, 2015). Despite offering many advantages, it seems that authors may have different preferences toward international collaboration. The lack of external collaboration may in part be due to the publication of case reports, which are by their very nature based on data from a single location. In the case of NPS, rapid dissemination of information is crucial, and sometimes the priority may be to get the research published, rather than waiting for extensive collaboration or confirmation. This approach enables researchers to quickly respond to emerging NPS, share their findings with the scientific community, raise awareness about potential health risks associated with these substances, and inform drugs legislation.

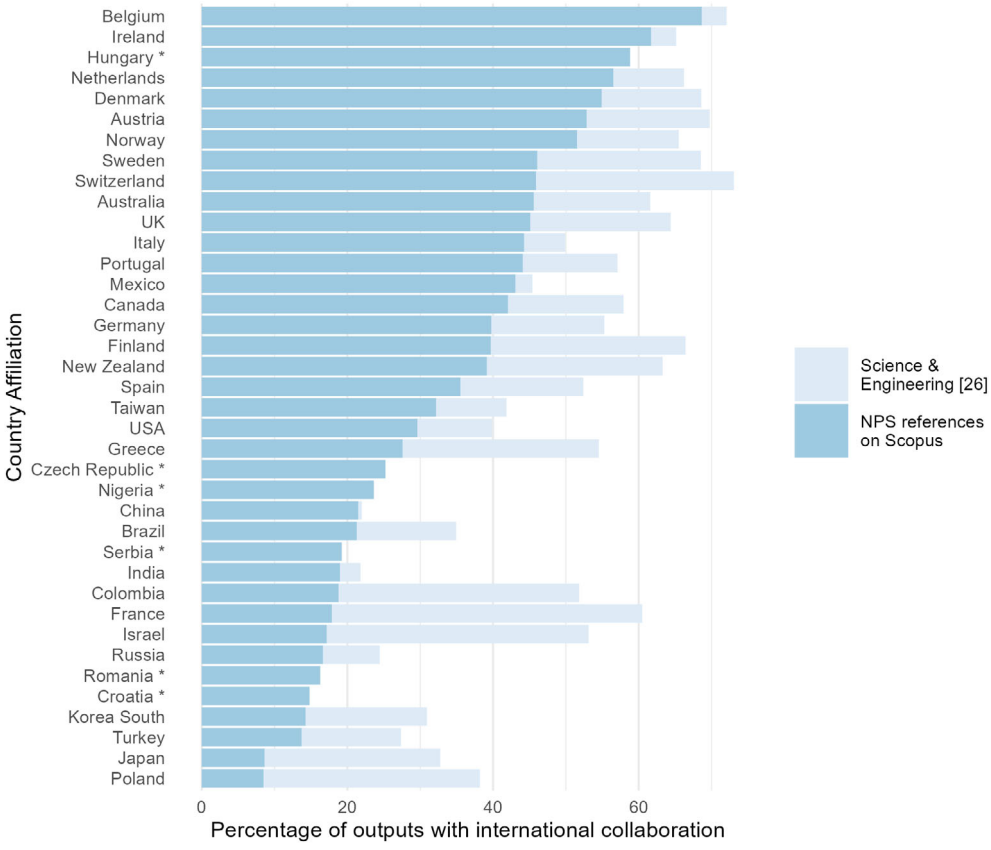

FIGURE 6 Percentage of records internationally connected for the top 36 countries with the highest number of documents. In dark blue the percentage of documents with international co-authorship for the Scopus search on NPS compounds; in light blue the percentage of documents with international co-authorship for Science & Engineering Indicators 2022 ("Science & Engineering Indicators," 2022). Countries labeled with an (*) were not cited in Science & Engineering Indicators 2022 ("Science & Engineering Indicators," 2022).

Research on emerging drugs is used to inform national and international legislation aimed at controlling and regulating emerging drugs. Countries and societies across the world continuously make, undo, or change their drugs laws in response to changes in the illicit drug market; however, countries often only impose regulations when a drug poses health concerns within their own borders, resulting in differing legislation in neighboring countries. A general assessment of the policies related to NPS in six EU countries was performed by Neicun et al. (2019). The authors found that while the policies were appropriate within the individual countries, the lack of standardization meant a cohesive strategy between countries was not reached. However, the implementation of legislation can be expected to have implications going beyond national public health strategies. The 2018 UN report highlighted that the majority of countries reported crime being tightly interlinked with drug movement across borders, as illicit drug networks expand across the globe (UNODC, 2018). It is, therefore, crucial to acknowledge the influence legal reforms have on drug restrictions, production, and distribution networks across international borders, as these changes not only impact public health but also have significant implications for criminal activities associated with the drug trade. This demonstrates the importance of international collaboration not just in the research on drugs but also in the national and international responses to changes in the illicit drug market, such as legislation.

One challenge facing lawmakers is the comprehension of legislation for countries using a different language, especially if there are no known official translations available. In their study of seized materials after the class-wide ban of synthetic cannabinoids in China in July 2021, Liu et al. provided a translation of the legislation for non-Chinese speakers(Office of China National Narcotics Control Commission (NNCA), 2021); however, a mistranslation was identified where "alkyl" was used instead of "hydrocarbyl" (Liu et al., 2022). The naming of NPS can also pose a significant challenge for lawmakers, practitioners and researchers as the IUPAC names of compounds are often found to be too long, resulting instead in the use of abbreviations (Zapata et al., 2021). This can lead to a single NPS having more than one acronym, bringing confusion and slowing down communication between practitioners and researchers from different institutions (Zapata et al., 2021). There is a naming convention for NPS; however, it only started recently in an attempt to address the lack of a global classification of the substances and is not yet used consistently worldwide (Zapata et al., 2021). To reduce future miscommunications, Zapata et al. proposed that NPS names (acronyms or abbreviations) should be accompanied by their CAS number and/or their chemical structure (Zapata et al., 2021).

While there are many benefits in collaborating internationally, this does not necessarily mean it always has to be done via co-authoring. The data generated by the researchers in each study can indirectly create connections between works. This is for example the case for the online mass spectral database HighResNPS. Its content is kept up to date with the contribution of many forensic laboratories around the world. This collective database can be searched by scientists and practitioners but also can permit new research to be built on as it has been for the work by Skinnider et al. (2021) which can predict the early identification of new compounds not yet in any reference lists. Depositing results into a database should aim at ensuring reliability and validity in research. It would be reasonable to expect that peer-reviewed materials come with their data (curated in an accepted format) which would have been deposited in a repository with a persistent identifier (i.e., digital object identifier [DOI]). The inclusion of data location can easily be part of the data submission when adding entries into a database. Such action would create links between published documents and the listed materials in the database. Interestingly, such action is not limited to peer-reviewed literature as it can also be applied to other forms of documentation that could be distributed within the community. Indeed, this work analyses documents listed on Scopus but this content cannot be considered comprehensive. The data from unpublished, non-commercial, government reports, conference proceedings, graduate dissertations, and so on, also known as the gray literature, but also can be included under the same concept. Such an approach would not only encourage greater data transparency but also a broader distribution of the findings as well as a wider inclusion of the community. The inclusion of all work carried out in the analysis of NPSs, either as reference standards or acquired in seizures, would rapidly highlight trends and lead to collaborative efforts.

4 | CONCLUSION

The present study used a scientometric approach to identify trends for drugs as an evidence type in forensic science by looking at reference lists available in the INTERPOL IFSMS reports and in the citation database Scopus. It was observed that "new psychoactive substances" is one of the most frequently used keywords by the authors of the documents. This demonstrates the increasing interest and swift response of the academic and practitioner communities to research and characterize these rapidly emerging compounds.

The analysis of the literature focused on the Scopus output for NPS revealed strong similarity in which compounds are mainly analyzed across countries. However, the results also seemed to show that a significant number of compounds have yet to be reported in the scientific literature despite being listed in databases such as HighResNPS. This supports the argument that a more comprehensive coverage of the literature and findings is required, including references from multiple sources rather than focusing on the scientific literature alone. This also highlights the need to include gray literature for greater transparency and broader distribution of findings.

Finally, despite drug misuse being a global threat, only limited international collaboration was observed between research groups as the majority of the studies are from authors affiliated within the same country. While this does not hinder the reporting of research results, collaboration remains an effective way to disseminate information on new compounds and methods within the community.

AUTHOR CONTRIBUTIONS

Caitlyn Norman: Supervision (equal); writing – original draft (equal). **Dorothy Xi Yue Lim:** Methodology (equal); software (equal); writing – original draft (equal). **Taylor Henderson:** Methodology (equal); software (equal); writing – original draft (equal). **Fabio Casali:** Supervision (equal); writing – original draft (equal). **Niamh Nic Daéid:** Funding acquisition (equal); supervision (equal); writing – original draft (equal). **Lorna Nisbet:** Supervision (equal); writing – original draft (equal). **Hervé Ménard:** Conceptualization (equal); methodology (equal); software (equal); supervision (equal); writing – original draft (equal).

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CONFLICT OF INTEREST STATEMENT

Niamh Nic Daeid is an Editor of the journal and was excluded from the peer-review process and all editorial decisions related to the publication of this article.

OPEN RESEARCH BADGES

This article has earned an Open Data badge for making publicly available the digitally-shareable data necessary to reproduce the reported results. The data is available at https://doi.org/10.5281/zenodo.8046815

DATA AVAILABILITY STATEMENT

The code and the data supporting this research are available via a persistent identifier at https://doi.org/10.5281/zenodo.8046815

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