Combining Internet Monitoring Processes, Packaging and Isotopic Analyses to Determine The Market Structure: Example of Gamma Butyrolactone

Abstract

The Internet is becoming more and more popular among drug users. The use of websites and forums to obtain illicit drugs and relevant information about the means of consumption is a growing phenomenon mainly for new synthetic drugs. Gamma ButyroLactone (GBL), a chemical precursor of Gamma Hydroxy Butyric acid (GHB), is used as a "club drug" and also in drug facilitated sexual assaults. Its market takes place mainly on the Internet through online websites but the structure of the market remains unknown. This research aims to combine digital, physical and chemical information to help understand the distribution routes and the structure of the GBL market. Based on an Internet monitoring process, thirty-nine websites selling GBL, mainly in the Netherlands, were detected between January 2010 and December 2011. Seventeen websites were categorized into six groups based on digital traces (e.g. IP addresses and contact information). In parallel, twenty-five bulk GBL specimens were purchased from sixteen websites for packaging comparisons and carbon isotopic measurements. Packaging information showed a high correlation with digital data confirming the links previously established whereas chemical information revealed undetected links and provided complementary information. Indeed, while digital and packaging data give relevant information about the retailers, the supply routes and the distribution close to the consumer, the carbon isotopic data provides upstream information about the production level and in particular the synthesis pathways and the chemical precursors. A three-level structured market has been thereby identified with a production level mainly located in China and in Germany,

an online distribution level mainly hosted in the Netherlands and the customers who order on the Internet.

Keywords: Internet monitoring processes; Packaging; Carbon isotopic analyses; Gamma Butyrolactone; Intelligence; Market structure; Digital Trace; Drug Profiling

1. Introduction

Due to the availability of many new recreational drugs online, the Internet is a key source of information in identifying new trends of drug abuse. Despite efforts of different governments to combat this virtual market, the online purchase of psychoactive compounds, in particular synthetic drugs, has grown significantly. In fact, due to the magnitude and accessibility of the Internet, the amount of customers buying substances called “legal highs” or “research chemicals” has increased [1]. Online platforms are generally hosted in countries where these substances are still permitted. This new trend tends to replace traditional exchanges between consumers and dealers on the street. Moreover, due to the rapid spread of new synthetic substances, the precise effects are still unknown or little known [2]. This study has been focused on Gamma Butyrolactone (GBL), the main chemical precursor of Gamma Hydroxy Butyric acid (GHB), which is directly converted into GHB in the body after ingestion [3, 4]. Recent surveys indicate that the consumption of GBL is a growing trend among drug users aiming to replace the consumption of GHB. This seems to be mainly due to its availability on the Internet and the lack of control in many countries [5]. The global production of GBL worldwide exceeds 200,000 tons per year and as it is an important and common industrial solvent which is used in large quantities as an intermediate in the synthesis of plastics,

polymers or pesticides among others, it is hardly controlled under national or international laws [6].

Nevertheless, the use of the Internet opens new perspectives to analyze and understand these phenomena in order to implement more proactive strategies against trafficking. In that respect, some projects have emerged in Europe under the umbrella of the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) using Internet monitoring processes and dedicated databases storing newly identified substances in order to give crucial information regarding health risks. However, little research has been published concerning Internet monitoring processes of known psychoactive substances aimed at acquiring a better understanding of the market for intelligence purposes [7].

From a forensic perspective, such global and strategic knowledge is fundamental in order to understand the research problem, select a representative sampling and make relevant and realistic assumptions. When it comes to common source inference or chemical profiling, these assumptions will depend on manufacturing processes such as syntheses pathways, the number of batches or the amount of psychoactive substance contained in batches as well as supply routes and distribution networks. Therefore, the knowledge of the market structure from the production line to the consumer is essential to interpret chemical links between two or more specimens. Such links are assumed to depict that specimens are probably coming from a same "source" but how can we define this specific "source"? [8, 9] Concerning GBL and depending on the market structure, the "source" could be defined as the producer, the synthesis pathway, the batch or even the Internet retailer.

In the present project, we investigate the potential of gathering several forensic information namely, digital, physical and chemical to gain a better understanding of the overall GBL market structure. An Internet monitoring methodology has been implemented for the

detection and the following of websites selling GBL and the detection of links based on digital traces. From specimens purchased on different websites, packaging information was collected in order to confirm or detect new links. Finally, by comparing the variation in the carbon isotopic composition of GBL specimens, chemical linkages were identified. The combination of digital, physical and chemical links is then globally discussed.

2. Materials and methods

2.1. GBL Internet Monitoring Process

A monitoring methodology of the websites selling GBL was set up. The aim of this monitoring process was to establish an effective search strategy of the GBL websites and above all to detect similarities during the creation and the hosting of the websites in order to infer linkages between these entities [10, 11]. For that purpose, twelve specific keywords combining different GBL names "GBL", "Gamma Butyrolactone" or "γ-Butyrolactone" with simple keywords in English like "cleaner", "buy" or "supplier" were initially chosen for the search of GBL websites with Google.com® search engine. Complementary searches were carried out with other keywords ("purchase/sell/order") and GBL street names using different tools like natural language ("Where to buy Gamma Butyrolactone?") and Google® multilingual search.

As a second step, an automatic alert system (Google Alert®) and a page change monitoring system (ChangeDetection.com) were implemented in order to detect the emergence of new websites and provide information about those already identified. Both alert systems were used to follow the evolution and the dynamic of the online GBL market. The results obtained by this monitoring process were then compared to previous results collected in 2010 [12].

2.1.1 Websites geolocation

Once the websites were indexed, several elements were gathered in order to carry out geographical analyses. Initially, information concerning the provenance of the product, and the distribution worldwide such as the geographical area of sale were considered. On one hand, the study of website content was performed, including the visible content and the language used to comment source code, the product origin (sometimes written on the website) and the contact address. On the other hand, analysis of the technical data such as extracting the IP address with the WHOIS protocol gives an indication of the hosting country, the country of the registrar, the registrant and the technical contact (**Table 1**).

Table 1: Information collected for website geolocation

Geographical information	**Information collected**
Origin and distribution	Provenance of the product and geographical area of sale
Website content	Site language, source code language and contact address
Technical data	Geolocation of the IP address, registrar and registrant country and technical contact

2.1.2 Digital links

In addition to geographical information, other similarities between the GBL websites were sought. For that purpose, various information was collected and compared between the different websites:

- Website content: URL addresses, logos on the browser tab (i.e. favicon), contact data (name, address, phone number) and bank details.
- Technical data: IP addresses of the server hosting the site, the subnets of the IP address and the contact of the owner, the HTTP header of the server, Google® markers whose “Google Adsense®” and “Google Analytics®”, scripts on the source

code, the “robot.txt” file and finally the WHOIS data of the domain name (registrar and registrant information).

All these searches were performed manually, using “nslookup” to identify the IP addresses and the “Firebug” plugin of Firefox® to read the scripts. Subnets information and the contact of the owner were obtained on the “www.iana.org” website while the data related to the registration of the domain name and the HTTP header information were obtained on the sites “whois.domaintools.com” and “www.webrankinfo.com/outils/header.php” respectively.

2.2. Sampling

Twenty-five bulk GBL specimens were purchased online from sixteen websites among the thirty-six detected in order to proceed with physical and chemical analyses. Multiple specimens were also ordered from a subset of the websites **(Table 2)**. It was decided to order new specimens every six months assuming that after such a period, a whole batch may probably have been sold.

Table 2: Bulk GBL specimens ordered on the websites.

GBL Websites (URL)	Names and Specimens
www.alco-international.nl	Alco International
www.all-chemicals.com	All-chemicals
www.alloycleaner.com	Alloycleaner
www.clean-crystal.com	GBLCleanCrystal
www.cleanmagic.de	Cleanmagic
www.cleanmpower.com	CleanMPower
www.cleanstar24.pl	Cleanstar 24 (Specimen 1)
www.cleanstar24.pl	Cleanstar 24 (Specimen 2)
www.gammabutyrolactone.cn	Everchem
www.gbl24.com	GBL24 (Specimen 1)
www.gbl24.com	GBL24 (Specimen 2)
www.gbl24.com	GBL24 (Specimen 3)
www.gblcleaner.eu/.nl	GBLcleaner
www.gblstarcleaner.com	GBLstarcleaner (Specimen 1)
www.gblstarcleaner.com	GBLstarcleaner (Specimen 2)
www.gblstarcleaner.com	GBLstarcleaner (Specimen 3)
www.liquidsoap.cc	Liquidsoap
www.multicleaner.eu	Multicleaner (Specimen 1)

www.multicleaner.eu	Multicleaner (Specimen 2)
www.multicleaner.eu	Multicleaner (Specimen 3)
www.odegasupercleaner.nl	Odergasupercleaner (Specimen 1)
www.odegasupercleaner.nl	Odergasupercleaner (Specimen 2)
www.rapidcleaner.com	Rapidcleaner
www.shineandbright.com	Shine & Bright (Specimen 1)
www.shineandbright.com	Shine & Bright (Specimen 2)

Eight GBL specimens coming from four different alleged producers were also purchased on a trade website (www.alibaba.com) selling products directly from manufacturers. These specimens originated in China, one of the most important GBL producers. No digital analyses were performed on this website since it gathers together products from several producers.

2.3. Physical links: Packaging

The twenty-five bulk GBL specimens were received in different plastic bottles. Physical information, such as the color, size, diameter and type of stopper, was collected from the bottle. Additionally, information including the name, size, design and language, was obtained from the label. All this information was used for comparisons between specimens and to identify "physical links". No physical or analytical analyses were performed on bottles, only visual comparisons.

2.4. Chemicals and Carbon isotopic measurements on a GC/C/IRMS

Dichloromethane (≥ 99.9%) was purchased from Merck (Darmstadt, Germany). ε-Caprolactone (≥ 99.0%, Lot 1256826) was obtained from Fluka (Buchs, Switzerland). Helium (Quality 60, > 99.9999%) and carbon dioxide gas (Quality 40, > 99.99%) were purchased from Carbagas (Domdidier, Switzerland). Tetradecanoic acid methyl ester (C14:0, #14M, $C_{15}H_{30}O_2$, $\delta^{13}C$ = -29.98 ± 0.02‰, > 99.0%) was obtained from Arndt Schimmelmann (Indiana University, Department of Geological Sciences, Biogeochemical Laboratories, 1001 East 10th Street, Bloomington, IN, USA).

Carbon isotopic measurements were performed three times at six months interval. The carbon isotope measurements were performed on a Delta V Plus IRMS system (ThermoFisher Scientific Inc., Bremen, Germany) coupled to a Trace GC Ultra Gas Chromatograph via a Finnigan™ GC-C/TC III interface (ThermoFisher Scientific Inc., Bremen, Germany). The samples were injected via a TriPlus^{TM} autosampler (ThermoFisher Scientific Inc., Bremen, Germany). The mass spectrometer consisted of an electron impact source held at 3.0 kV acceleration voltage for CO_2 gas, a magnet and three Faraday collectors for measurement of the ions at *m/z* 44, 45 and 46. Concerning the sample preparation, 150 µL of ε-caprolactone (Internal Standard, 20 µg/mL in dichloromethane) and 50 µL of tetradecanoic acid methyl ester (Isotope Calibrator, 10 µg/mL in dichloromethane) were mixed to 100 µl of GBL (100 µg/mL in dichloromethane). After vortex-mixing for 5 sec, GC/C/IRMS analyses were performed according to the methodology previously published [12].

The symbol δ is the standard notation for expressing carbon isotope ratios. It is defined as parts per thousand deviations of isotopic compositions from that of Vienna Pee Dee Belemnite (VPDB) and is calculated according to [13]:

$$\delta^{13}C\,/\,‰ = \frac{(^{13}C/^{12}C)_{sample} - (^{13}C/^{12}C)_{standard}}{(^{13}C/^{12}C)_{standard}} \times 1000 \quad (1)$$

Acquisition and evaluation of the GC/C/IRMS data were performed with the ISODAT 2.5 software (ThermoFisher Scientific, Bremen, Germany).

179 *2.3.2 Threshold setting and chemical links*

180 The intra variability values were calculated as the differences in the carbon isotope ratio
181 between each of the replicates of the twenty-five GBL bulk. The inter variability values were
182 established as the differences between the carbon isotope ratio means of the sixteen different
183 GBL retailers. The evaluation of the overlapping area between the inter variability and the
184 intra variability of the distribution $\delta^{13}C$ -values was performed by calculating the true and
185 false positive rates. This study has been carried out for operational and intelligence purposes
186 in order to increase our understanding of the GBL market and provide strategic information
187 instead of providing evidence in court. For that reason, the threshold has been set up to detect
188 all possible links (true positive rate maximized) and accepting higher values for the false
189 positive rate. On the contrary, if the aim were to compare GBL specimens for evidence
190 purposes, the false positive rate would have been minimized at the expense of the true
191 positive rate. Therefore, a threshold of $\delta^{13}C$ 0.9‰ was established enabling discrimination
192 between "chemically" linked and "non-chemically" linked GBL specimens. The statistical
193 analyses and calculations were performed with Excel® while I2 Analyst's Notebook® was
194 used for the visual representation of the linkages.

195

196 **3. Results and Discussion**

197 *3.1 Internet Monitoring Process*

198 A total of thirty-six websites were initially detected with our methodology in June 2011.
199 Twenty-seven of these websites were found using the keyword "GBL cleaner" while only
200 four were found by complementary keyword combinations or natural language search and two
201 Ukrainian websites were detected with the multilingual search of Google®. From June to
202 December 2011, the follow-up of the GBL websites showed three additional sites. Finally,

thirty-nine websites selling GBL were discovered with the automatic alert systems previously established.

These results were compared with a previous search performed in January 2010 as part of another study in which twenty-six websites were found using a traditional search on Google.com® without any alert or automatic systems **(Figure 1)** [12].

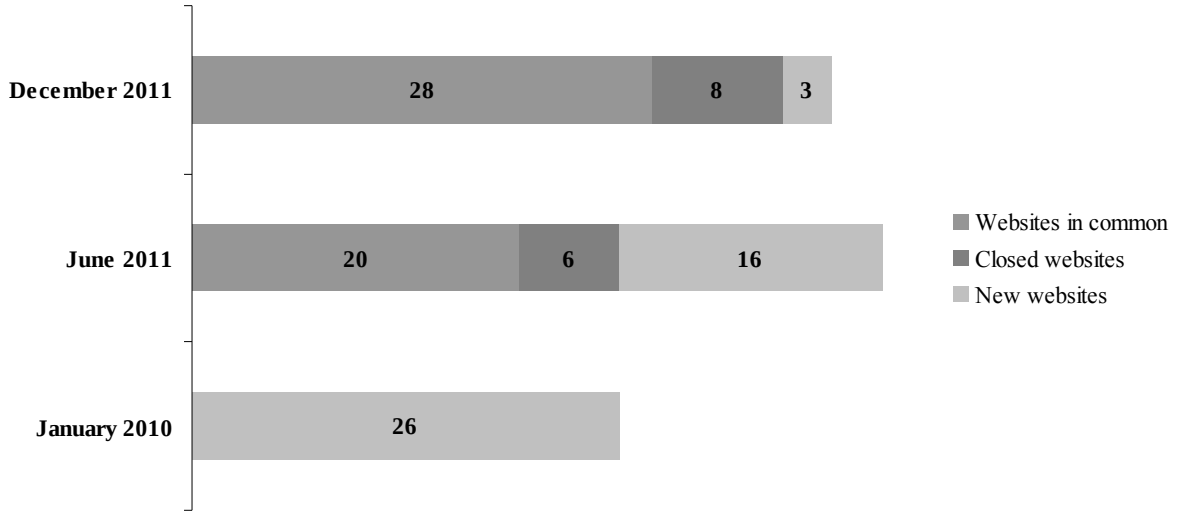

Figure 1: Follow-up of the GBL websites from January 2010 and December 2011

As shown in Figure 1, sixteen new websites were detected and six were closed from January 2010 to June 2011. Only three new websites were detected and eight closed from June to December 2011. Moreover, twenty websites, already identified in January 2010, were detected in June 2011 and twenty-seven websites, already brought out in June 2011, were found in December 2011.

These results showed that the GBL online market seems fairly stable between 2010 and 2011 and how easy it is to find GBL websites with simple keywords and without any previous knowledge of the market. Some of the new websites detected between 2010 and 2011 were probably due to the improvement of specific search criteria and the establishment of the automatic alert system. In fact, a high number of websites (69%) remain from previous

searches and only a small number have been closed. On one hand, this stability can be a relevant indicator of the lack of control measures against these websites on the Internet. On the other hand, the websites are versatile and may tend to be located in countries where the substance is not under control and where the laws are more flexible. Then, research was undertaken to identify the countries that supply the GBL and the ones who host the websites.

3.1.1 Websites geolocation

Most of the websites distribute GBL worldwide with some restrictions for countries such as USA, Canada, Australia, New Zealand and Norway where GBL is prohibited. Some of the websites (less than 50%) indicate that the provenance of the GBL is mainly China and Germany. Indeed, GBL manufacturers are mostly based in China, Germany (BASF), India (Balaji Group) or the USA (Lyondell and Ashland) and belong to important chemical companies [14]. In 2012, BASF manufactured more than 60,000 tons per year while in China, more than 20 GBL producers were active in 2005 and the total capacity of GBL manufacturing was reported in 2006 to be around 50,000 tons per year, 33,000 of which were exported [15].

One of the issues was to investigate if the websites were hosted in the manufacturing countries. It is worth noting that IP addresses may not be directly linked to the retailer's location. Indeed, websites may be hosted in foreign countries and spoofing strategies may also be used to hide the true location of the machine. Therefore, Information found on websites including the source code language, the site language and the personal information (contact address, phone number, etc.) has also been investigated for comparison. The combination of these pieces of information is highly relevant, in particular the source code and site language, which are mainly related to the designer of the website who may certainly

use his own language for commenting the source code. By comparing the geolocation using Information found on websites and IP addresses geolocation, the most significant difference concerns three websites that had IP addresses in Czech Republic, Germany and the Netherlands but were built in polish and the contact addresses on these websites were from Poland.

According to the results shown in **Figure 2** and detailed in **Table 3**, more than 60 % of the websites were coming from the Netherlands where GBL is not controlled by national law. These results point out that most of the websites are hosted in countries that do not have official manufacturing companies such as the United Kingdom, Poland and mostly the Netherlands. Since the geolocation of websites is different from GBL producer countries, these GBL Internet websites seem to act as retailers between costumers and manufacturing companies. They have an intermediary level function, which will be called "the distribution level" in the market structure.

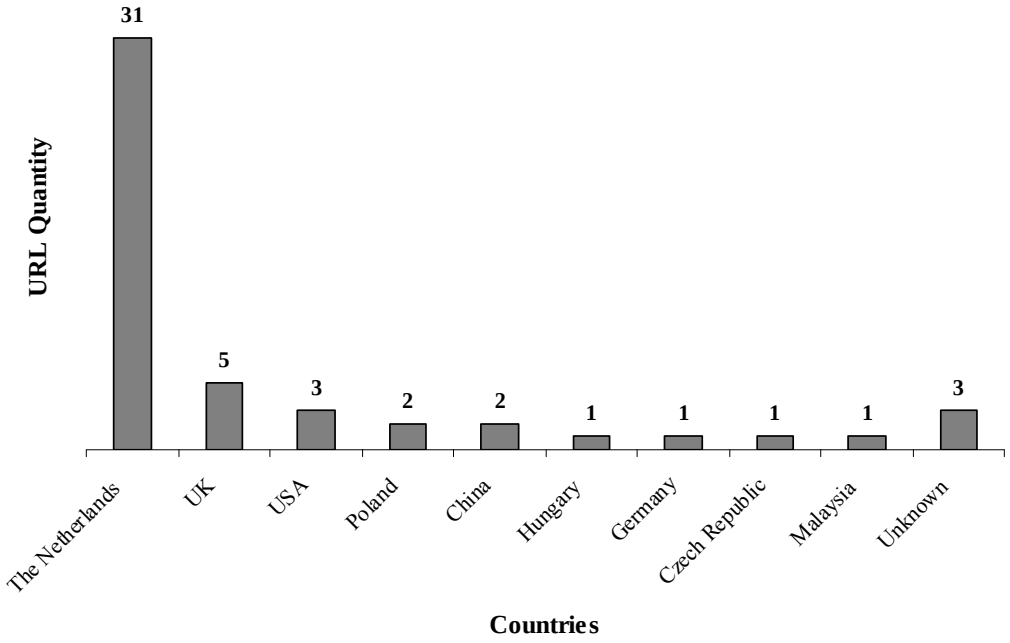

Figure 2: Geolocation of the GBL websites considering IP addresses

Table 3: Results of the websites geolocation. DNS (Data Not Shown)

Names and specimens	Specimens	Geolocation (Technical info)	Geolocation (Websites content)
Alco International	Specimen 1	The Netherlands	The Netherlands
All-chemicals	Specimen 1	Germany	Poland
Alloycleaner	Specimen 1	DNS	UK
GBLCleanCrystal	Specimen 1	Bulgaria	Poland
Cleanmagic	Specimen 1	The Netherlands	The Netherlands
CleanMPower	Specimen 1	Poland	Poland
Cleanstar 24 (Spec. 1)	Specimen 1	The Netherlands	Poland
Cleanstar 24 (Spec. 2)	Specimen 2	The Netherlands	Poland
Everchem	Specimen 1	China	China
GBL24 (Spec. 1)	Specimen 1	DNS	Poland
GBL24 (Spec. 2)	Specimen 2	DNS	Poland
GBL24 (Spec. 3)	Specimen 3	DNS	Poland
GBLcleaner	Specimen 1	The Netherlands	DNS
GBLstarcleaner (Spec. 1)	Specimen 1	The Netherlands	Germany
GBLstarcleaner (Spec. 2)	Specimen 2	The Netherlands	Germany
GBLstarcleaner (Spec. 3)	Specimen 3	The Netherlands	Germany
Liquidsoap	Specimen 1	DNS	UK
Multicleaner (Spec. 1)	Specimen 1	The Netherlands	The Netherlands
Multicleaner (Spec. 2)	Specimen 2	The Netherlands	The Netherlands
Multicleaner (Spec. 3)	Specimen 3	The Netherlands	The Netherlands
Odergasupercleaner (Spec. 1)	Specimen 1	USA	The Netherlands
Odergasupercleaner (Spec. 2)	Specimen 2	USA	The Netherlands
Rapidcleaner	Specimen 1	Czech Republic	Poland
Shine & Bright (Spec. 1)	Specimen 1	The Netherlands	The Netherlands
Shine & Bright (Spec. 2)	Specimen 2	The Netherlands	The Netherlands

Complementary research has been undertaken to highlight similarities between various websites in order to make assumptions about the amount of retailers and how they are structured.

3.1.2 Digital links

Seventeen of the thirty-nine websites were categorized into six groups (**Figure 3**). Most of the websites were linked by at least two separate sources of information. For instance, in the upper right section of Figure 3, “Magic Cleaner” and “Astro Lab” were connected by three pieces of information: the IP address, contact information on the website and the *Google*® *Analytics* markers. These markers are unique codes specific to customers and are used by

webmasters to follow the traffic on their websites. Therefore, this code is relevant to linking websites handled by the same group of persons. Moreover, phone numbers and IP addresses confirm the highlighted similarities and reinforce the linkages established between these websites.

It is important to note that online GBL retailers do not seem to be articulated around a small number of persons. The structure of the organization includes many small entities (one or two websites), which seem to be independent of each other, except for the two groups containing three and six websites.

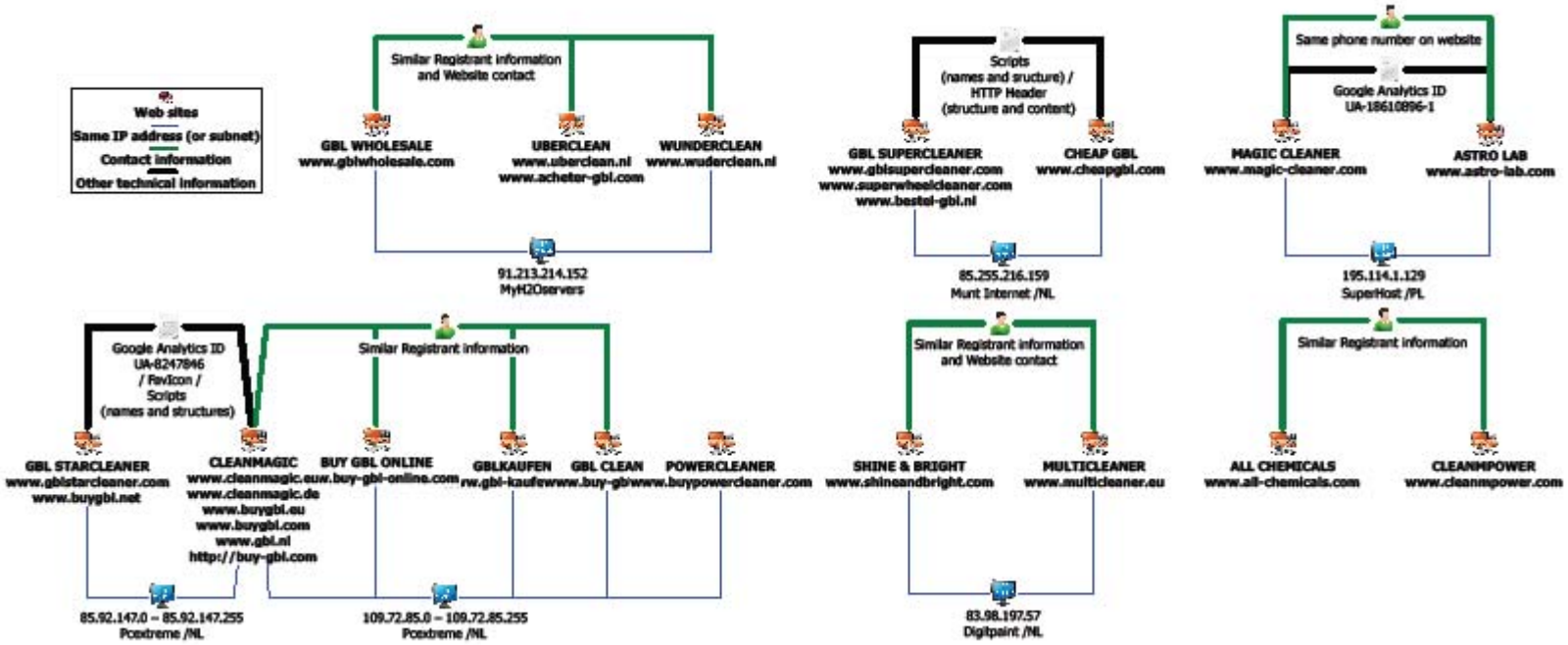

Figure 3: Schema showing all the GBL websites linked by digital information

As previously highlighted, the digital information concerns the distribution level and little information has been obtained regarding the production level and the dynamism of the market (interactions and flows between retailers and manufacturers). For instance, do retailers tend to order always from the same company or do they change their producer contacts to find cheaper products or on the contrary, purer products? To answer these questions, the investigation of the physical and chemical information is required.

3.2 Physical links: Packaging

Packaging information may provide clues on the retailers and the supply routes based on the hypothesis that the retailers receive the GBL in big containers and have to pack the samples in bottles before sending them with specific labels. Indeed, the results **(Table 4)** show that packaging tends towards confirming the links previously established by the digital information and seems to help understand the distribution network. Sixteen specimens (ten websites) were linked and categorized into five groups. Three of the five groups were already connected by digital information while two groups of two websites were only linked by physical information.

Table 4: Results of the obtained physical links

Groups	Physical link	Type of link	Specimens linked
1	A	Bottle	GBLstarcleaner (Specimen 1), GBLstarcleaner (Specimen 2), GBLstarcleaner (Specimen 3) and Cleanmagic
2	B	Label	Liquidsoap and Alloycleaner
3	C	Label	Shine & Bright (Specimen 1) and Multicleaner (Specimen 1)
	D	Bottle	Shine & Bright (Specimen 1), Multicleaner (Specimen 1) and Multicleaner (Specimen 2)
	E	Bottle	Shine & Bright (Specimen 2) and Multicleaner (Specimen 3)
	F	Label	Shine & Bright (Specimen 2), Multicleaner (Specimen 2) and Multicleaner (Specimen 3)
4	G	Label	CleanMPower and All-chemicals

5	H	Bottle	Cleanstar 24 (Specimen 1), Cleanstar 24 (Specimen 2) and Rapidcleaner

3.3 Determination of the chemical classes

Carbon isotopic analyses were performed on twenty-five GBL specimens coming from sixteen different websites as well as on eight GBL specimens coming from four alleged producers. The results showed a wide variation of δ^{13}C-values ranging from -23.11‰ to -45.74‰. Concerning the alleged Chinese GBL producers, the carbon isotopic values ranged from -27.54‰ to -29.83‰. All the δ^{13}C-values were associated with very low standard deviation (lower than 0.3‰) of triplicate analyses **(Table 5)**.

First, it was decided to compare the δ^{13}C-values with the geographical origin of GBL specimens specified on the websites even if this information is not always reliable. The results showed connections between the δ^{13}C-values and the country of origin of the GBL specimens. Indeed, GBL specimens originating from Germany showed carbon isotopic values ranging from -45.74‰ (Cleanstar24 Specimen 1) to -41.70‰ (GBL24 Specimen 2) except for GBLstarcleaner Specimen 1 (-27.09‰) while the δ^{13}C-values obtained for the Chinese specimens ranged from -30.02‰ (Everchem Specimen 1) to -23.11‰ (Shine&Bright Specimen 1). The enriched δ^{13}C-value of GBLstarcleaner Specimen 1 (-27.09‰) is probably due to the fact that this website (GBLstarcleaner), which sells two GBL qualities at different prices (German quality is more expensive than the Chinese one), seeks to sell lower GBL quality specimens from China under the label of a higher GBL quality from Germany. Concerning Odegasupercleaner, the website sent us, as specimen 1, GBL coming either from Germany or the USA without specifying which of the two and, as specimen 2, GBL supposedly from Poland that has no official manufacturing companies. Likewise, two countries of origin were specified by the website Cleanmagic (China and USA; -37.50‰).

Therefore, the country of origin given by these websites should be taken with precaution and they were not categorized neither in the Chinese nor in the German groups. Through these results, the potential of carbon isotopic analyses to differentiate between GBL originating from Germany and China was demonstrated but more specimens of producers from Germany and the USA are required as well as more information about the unknown specimens (DNS). Moreover, the differences in the δ^{13}C-values of GBL between pairs of specimens from different websites were calculated and the chemical classes were determined according to the threshold of 0.9‰ (in the δ^{13}C-values) previously established (**Figure 4**). This threshold allowed us to highlight five different chemical classes from A to E and four specimens (Cleanmagic, GBLcleaner, Alloycleaner and Shine & Bright) were not connected to any other specimen analyzed (**Table 5** and **Figure 4)**.

Table 5: Carbon isotopic values for GBL specimens ordered online. DNS (Data Not Shown)

Websites Names	Specimens	GBL origin	δ^{13}C-means (‰)	SD (‰)	Chemical class
Cleanstar 24	Specimen 1	DNS	-45.74	0.10	A
CleanMPower	Specimen 1	DNS	-45.52	0.05	A
GBL24	Specimen 1	Germany	-45.50	0.12	A
GBL24	Specimen 3	Germany	-44.27	0.21	B
Rapidcleaner	Specimen 1	Germany	-43.94	0.12	B
GBLCleanCrystal	Specimen 1	DNS	-43.60	0.02	B
All-chemicals	Specimen 1	Germany	-43.58	0.11	B
Cleanstar 24	Specimen 2	DNS	-43.58	0.16	B
GBL24	Specimen 2	Germany	-41.70	0.12	C
Odegasupercleaner	Specimen 1	Germany/USA	-41.55	0.11	C
Cleanmagic	Specimen 1	China/USA	-37.50	0.04	-
GBLcleaner	Specimen 1	DNS	-32.06	0.08	-
Everchem	Specimen 1	China	-30.02	0.09	D
Producer 1	**Specimen 1**	**China**	**-29.83**	**0.07**	**D**
Producer 1	**Specimen 2**	**China**	**-29.75**	**0.10**	**D**
Alco International	Specimen 1	China	-29.73	0.05	D
Multicleaner	Specimen 2	DNS	-29.64	0.08	D
Producer 2	**Specimen 1**	**China**	**-29.45**	**0.04**	**D**
Odegasupercleaner	Specimen 2	Poland	-29.44	0.06	D
Producer 2	**Specimen 2**	**China**	**-29.18**	**0.10**	**D**
Multicleaner	Specimen 1	DNS	-29.13	0.12	D
Multicleaner	Specimen 3	DNS	-29.05	0.05	D
Shine & Bright	Specimen 2	China	-28.95	0.18	D
Producer 3	**Specimen 1**	**China**	**-27.99**	**0.11**	**E**
Liquidsoap	Specimen 1	DNS	-27.97	0.10	E
GBLstarcleaner	Specimen 3	China	-27.86	0.11	E
Producer 4	**Specimen 1**	**China**	**-27.85**	**0.05**	**E**
GBLstarcleaner	Specimen 2	China	-27.82	0.03	E
Producer 4	**Specimen 2**	**China**	**-27.67**	**0.09**	**E**

Producer 4	**Specimen 3**	**China**	**-27.54**	**0.22**	**E**
GBLstarcleaner	Specimen 1	Germany	-27.09	0.18	E
Alloycleaner	Specimen 1	DNS	-24.13	0.08	-
Shine & Bright	Specimen 1	China	-23.11	0.04	-

In fact, classes A, B and C correspond to GBL specimens originating from Germany and classes D and E are related to specimens originating from China. Likewise, Chinese specimens of class D can be related with Chinese producers 1 and 2 while GBL specimens of class E correspond to Chinese producers 3 and 4.

Based on previous work, it can be assumed that the wide range of carbon isotopic values obtained for GBL specimens is due to the synthetic pathways and the starting material employed. In fact, several chemical precursors may be potentially used for the manufacturing of GBL at an industrial level [12]. The major portion of GBL is currently produced from the dehydrogenation of 1,4 Butanediol (1,4-BD), which is manufactured via the REPPE process from the reaction of acetylene with formaldehyde [16]. Other GBL manufacturing processes are based on economically attractive raw chemicals such as maleic anhydride [17, 18] and dimethyl maleate [19] via the Davy process. Almost all companies manufacturing GBL in Europe use the REPPE process in their production chain whereas in Asia both REPPE and Davy processes are often used [14]. New eco-friendly manufacturing routes using the biotransformation of natural starting materials such as glucose have also emerged recently [20]. Therefore, it may be expected that specimens of classes A, B, C (German specimens) and classes D, E (Chinese specimens) were manufactured via different synthesis processes and different feedstocks. Concerning the small differences in the $\delta^{13}C$-values between A, B and C as well as between D and E, it may be hypothesized that these specimens were manufactured through the same synthesis process but perhaps with different starting materials or different batches of the same starting material. This could explain the small differences in the $\delta^{13}C$-values found between these classes. Considering that the retailers can purchase GBL

366 from various producers, one of the assumptions to explain the differences in the $\delta^{13}C$-values
367 for specimens between class A and E may be that different GBL samples were mixed by the
368 retailers causing variation in the carbon isotopic value.
369
370

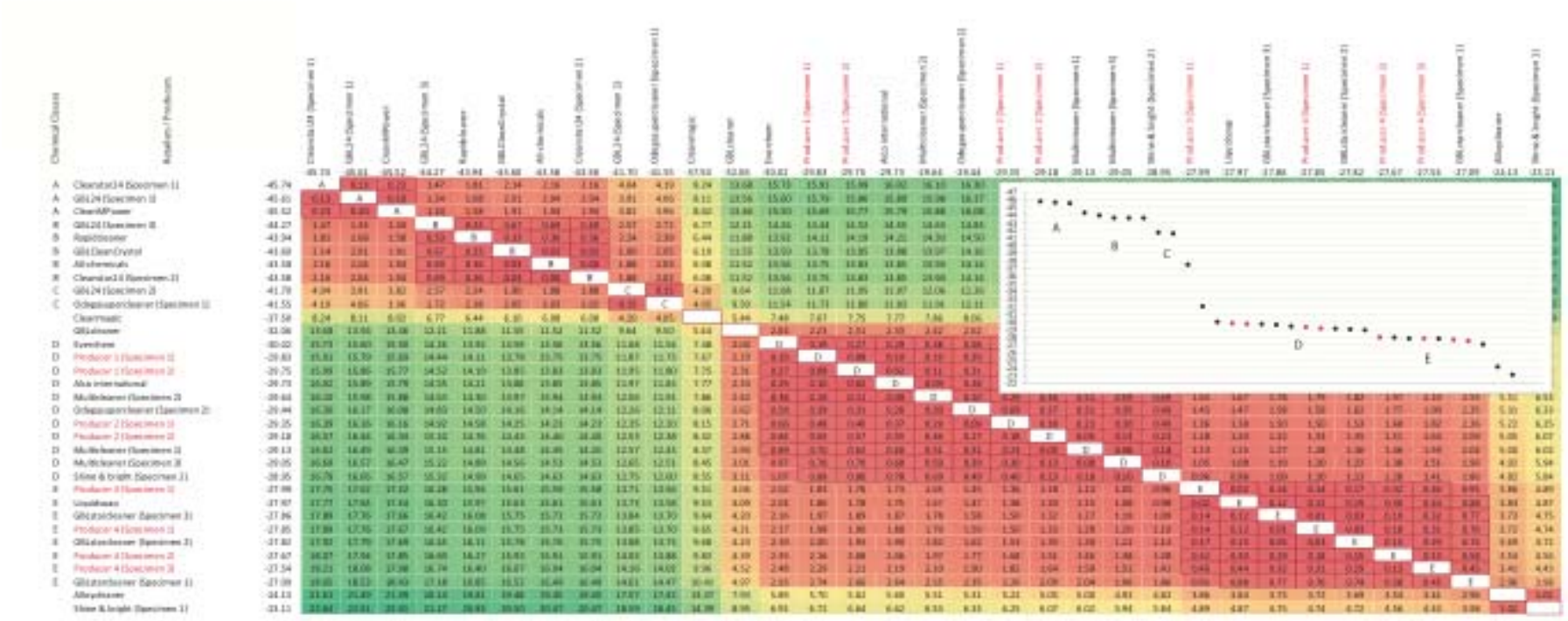

Figure 4: Visual representation of the chemical classes. The retailers are represented in black while the supposed producers are in red. Chemical links are framed in red and the name of the chemical class is indicated with letters.

3.4 Combining digital, physical and chemical information

By adding chemical information, nine new websites were indirectly connected **(Figure 5)**. It is worth emphasizing that the link between "Shine&Bright" and "Multicleaner", which was already observed with digital information, was confirmed by physical and chemical information. This example clearly demonstrates the potential of combining physical observations with chemical information. In fact, by merely exploiting chemical information, "Multicleaner specimens 1, 2 and 3" would have been linked to "Shine&Bright specimen 2" and not to "Shine&Bright specimen 1". By adding physical observations performed on the label and on the bottle, "Shine&Bright specimen 1" has been related to "Multicleaner specimens 1 and 2". As highlighted previously, packaging takes place at the distribution level and is therefore probably related to retailers more than producers. The combination of all of these sources of information strongly reinforces the hypothesis that the same group of people handled these websites. Moreover, some specimens ordered on the same website were linked to different websites. For instance, "Odegasupercleaner specimen 1" was connected to "GBL24 specimen 2" but they were not linked to other specimens. Knowing that the specimens were ordered every 6 months, it may be hypothesized that the manufacturers supplying these websites might have been replaced by producers selling cheaper or better quality products. This example enhances the fact that the chemical information doesn't link a specimen and its supplier (website) or two suppliers together. This information allows to link a specimen with a producer or to conclude that two unrelated websites got their supply from the same producer. Likewise, it is worth noting that chemical information provides relevant and complementary information regarding the production level and the flow routes between retailers and manufacturers.

In conclusion, it may be inferred that the online GBL market is structured in at least three levels. First, a production stage based on few synthesis routes and starting materials mainly located in China and Germany. Then, an intermediary level of supply and distribution highly visible on the Internet through websites mainly hosted in the Netherlands has been brought up and finally customers and consumers who order on the websites. In the industry, many official companies handle pure GBL without manufacturing it. A previous study, in 2003, by the Swedish National Institute of Public Health in relation to the flow of pure GBL in Sweden, showed that companies handling GBL might be importers, distributors, users or a combination of them [6]. All these trades are controlled but thefts cannot be excluded. The results obtained during the current study show that the combination of various sources of information opens new perspectives to understanding and obtaining background knowledge as well as providing relevant information in order to assist international organizations in their fight against drug trafficking, not only for GBL but also for others substances. The methodology proposed could be implemented in routine at two levels. The first level includes all the digital information and, in particular, the monitoring of the websites that can be easily standardized by national and international organizations (such as the federal police, EUROPOL or INTERPOL for instance). The second level covers all the physical and chemical analyses that would be performed, depending on the casework, by specialized laboratories. Finally, these laboratories should ideally convey information to national and international organizations.

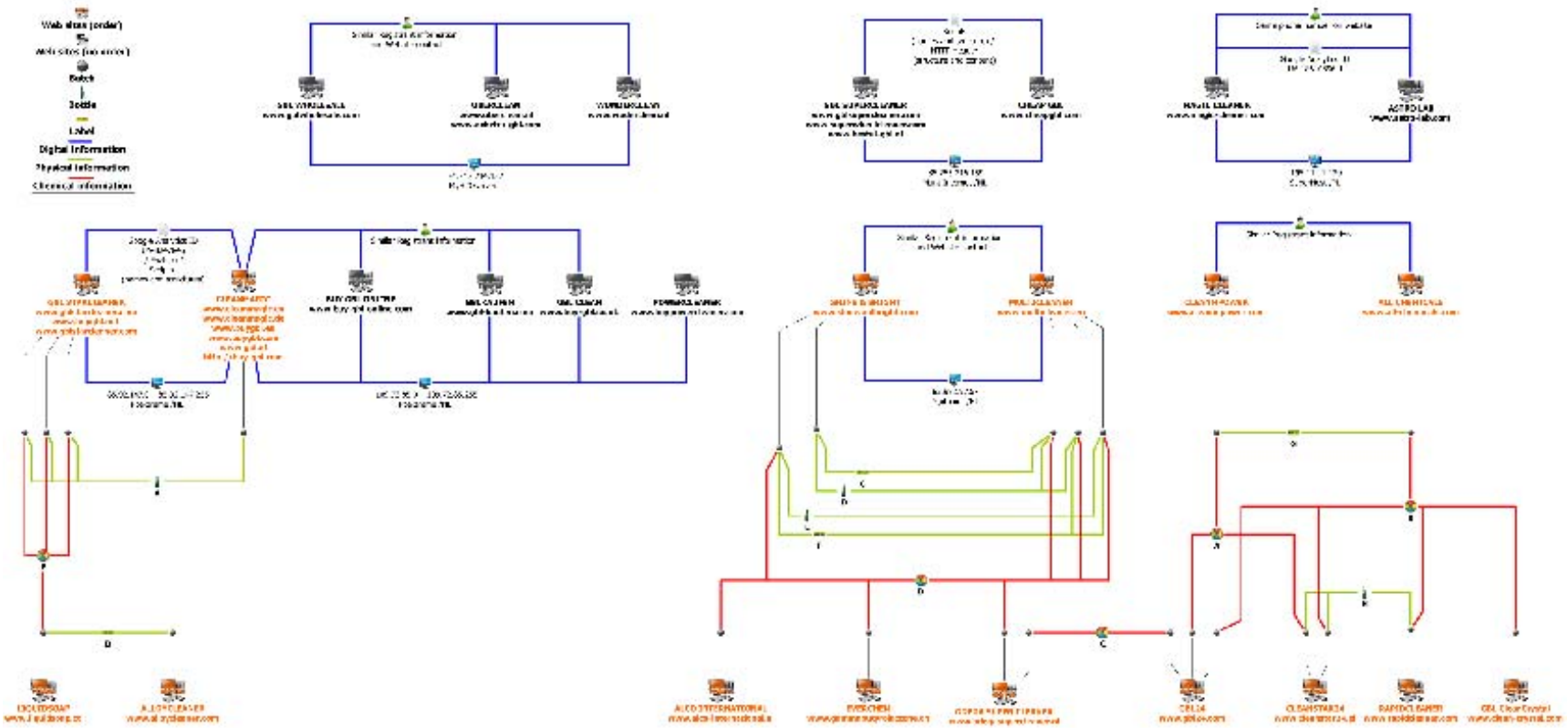

Figure 5: Schema combining digital, physical and chemical linkages obtained for the GBL websites.

4. Conclusion

A methodology for the monitoring of GBL websites was developed. A simple detection strategy using twelve keyword combinations showed great results in regard to more complex web searches. This monitoring process also required the design of a dedicated system that accommodated and organized collected data in a fitted working memory in order to detect relationships between websites and therefore, provide relevant information about the distribution market.

The results obtained so far emphasize the feasibility of a forensic approach combining multiple sources of information. They demonstrate that digital and physical data provide relevant information about the retailers, the supply routes and the distribution while the carbon isotopic composition provides upstream information about chemical links and concerns mainly the production stage. In order to further study the production step, isotopic profiling of GBL samples manufactured in the same industrial plant should be undertaken to establish the carbon isotopic variation within and between different batches.

The combination of various sources of information opens new perspectives to exploit forensic information in order to improve the common knowledge of drug market structures, not only for GBL but also for other substances. This knowledge is of major importance to correctly interpret the notion of "source inference". Finally, this research shows how digital traces may be combined with physical and chemical profiles extracted from specimens to gain a better insight into the phenomena from intelligence and investigative perspectives at national and international levels.

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