

1 **Combining Internet Monitoring Processes, Packaging and Isotopic** 2 **Analyses to Determine The Market Structure: Example of Gamma** 3 **Butyrolactone**

4 5 **Abstract**

6 The Internet is becoming more and more popular among drug users. The use of websites and
7 forums to obtain illicit drugs and relevant information about the means of consumption is a
8 growing phenomenon mainly for new synthetic drugs. Gamma Butyrolactone (GBL), a
9 chemical precursor of Gamma Hydroxy Butyric acid (GHB), is used as a “club drug” and also
10 in drug facilitated sexual assaults. Its market takes place mainly on the Internet through online
11 websites but the structure of the market remains unknown. This research aims to combine
12 digital, physical and chemical information to help understand the distribution routes and the
13 structure of the GBL market. Based on an Internet monitoring process, thirty-nine websites
14 selling GBL, mainly in the Netherlands, were detected between January 2010 and December
15 2011. Seventeen websites were categorized into six groups based on digital traces (e.g. IP
16 addresses and contact information). In parallel, twenty-five bulk GBL specimens were
17 purchased from sixteen websites for packaging comparisons and carbon isotopic
18 measurements. Packaging information showed a high correlation with digital data confirming
19 the links previously established whereas chemical information revealed undetected links and
20 provided complementary information. Indeed, while digital and packaging data give relevant
21 information about the retailers, the supply routes and the distribution close to the consumer,
22 the carbon isotopic data provides upstream information about the production level and in
23 particular the synthesis pathways and the chemical precursors. A three-level structured market
24 has been thereby identified with a production level mainly located in China and in Germany,

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

27

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

30

31 **1. Introduction**

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

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

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

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

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

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

77

78 **2. Materials and methods**

79 *2.1. GBL Internet Monitoring Process*

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

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

95

96 *2.1.1 Websites geolocation*

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

105
106 **Table 1:** Information collected for website geolocation
107

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

108

109 *2.1.2 Digital links*

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

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

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

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

125

126 2.2. Sampling

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

132 **Table 2:** Bulk GBL specimens ordered on the websites.

133

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)

134

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

139

140 *2.3. Physical links: Packaging*

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

147

148 *2.4. Chemicals and Carbon isotopic measurements on a GC/C/IRMS*

149 Dichloromethane ($\geq 99.9\%$) was purchased from Merck (Darmstadt, Germany). ϵ -
 150 Caprolactone ($\geq 99.0\%$, Lot 1256826) was obtained from Fluka (Buchs, Switzerland). Helium
 151 (Quality 60, $> 99.9999\%$) and carbon dioxide gas (Quality 40, $> 99.99\%$) were purchased
 152 from Carbagas (Domdidier, Switzerland). Tetradecanoic acid methyl ester (C14:0, #14M,
 153 C₁₅H₃₀O₂, $\delta^{13}\text{C} = -29.98 \pm 0.02\%$, $> 99.0\%$) was obtained from Arndt Schimmelmann
 154 (Indiana University, Department of Geological Sciences, Biogeochemical Laboratories, 1001
 155 East 10th Street, Bloomington, IN, USA).

156

157 Carbon isotopic measurements were performed three times at six months interval. The carbon
158 isotope measurements were performed on a Delta V Plus IRMS system (ThermoFisher
159 Scientific Inc., Bremen, Germany) coupled to a Trace GC Ultra Gas Chromatograph via a
160 Finnigan™ GC-C/TC III interface (ThermoFisher Scientific Inc., Bremen, Germany). The
161 samples were injected via a TriPlus™ autosampler (ThermoFisher Scientific Inc., Bremen,
162 Germany). The mass spectrometer consisted of an electron impact source held at 3.0 kV
163 acceleration voltage for CO₂ gas, a magnet and three Faraday collectors for measurement of
164 the ions at *m/z* 44, 45 and 46. Concerning the sample preparation, 150 µL of ε-caprolactone
165 (Internal Standard, 20 µg/mL in dichloromethane) and 50 µL of tetradecanoic acid methyl
166 ester (Isotope Calibrator, 10 µg/mL in dichloromethane) were mixed to 100 µl of GBL (100
167 µg/mL in dichloromethane). After vortex-mixing for 5 sec, GC/C/IRMS analyses were
168 performed according to the methodology previously published [12].

169

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

173

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

175

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

178

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 $\delta^{13}\text{C}$ -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 $\delta^{13}\text{C}$ 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

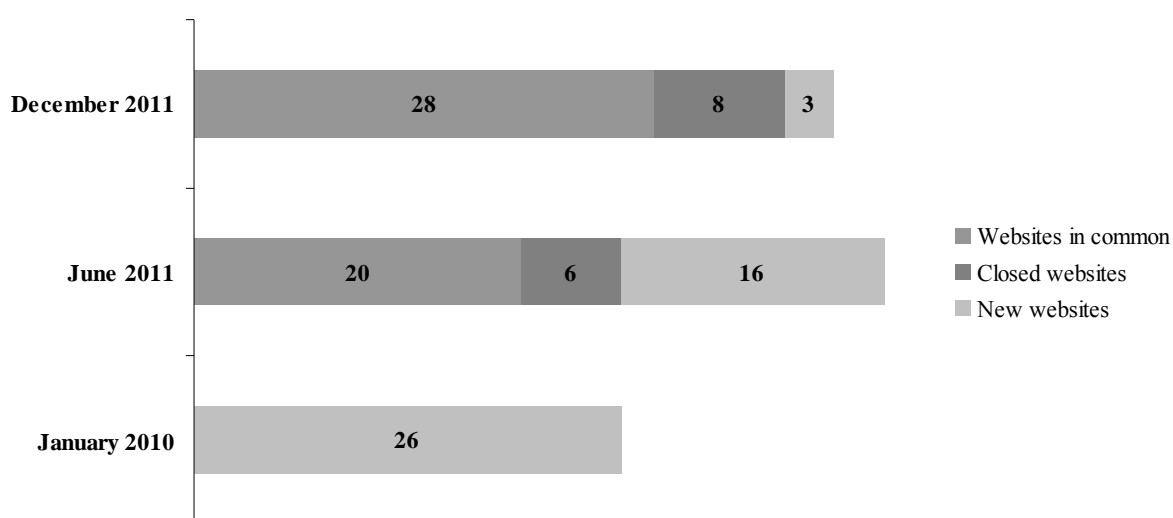
196 **3. Results and Discussion**

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,

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

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



208
209 **Figure 1:** Follow-up of the GBL websites from January 2010 and December 2011
210

211 As shown in Figure 1, sixteen new websites were detected and six were closed from January
212 2010 to June 2011. Only three new websites were detected and eight closed from June to
213 December 2011. Moreover, twenty websites, already identified in January 2010, were
214 detected in June 2011 and twenty-seven websites, already brought out in June 2011, were
215 found in December 2011.

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

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

226

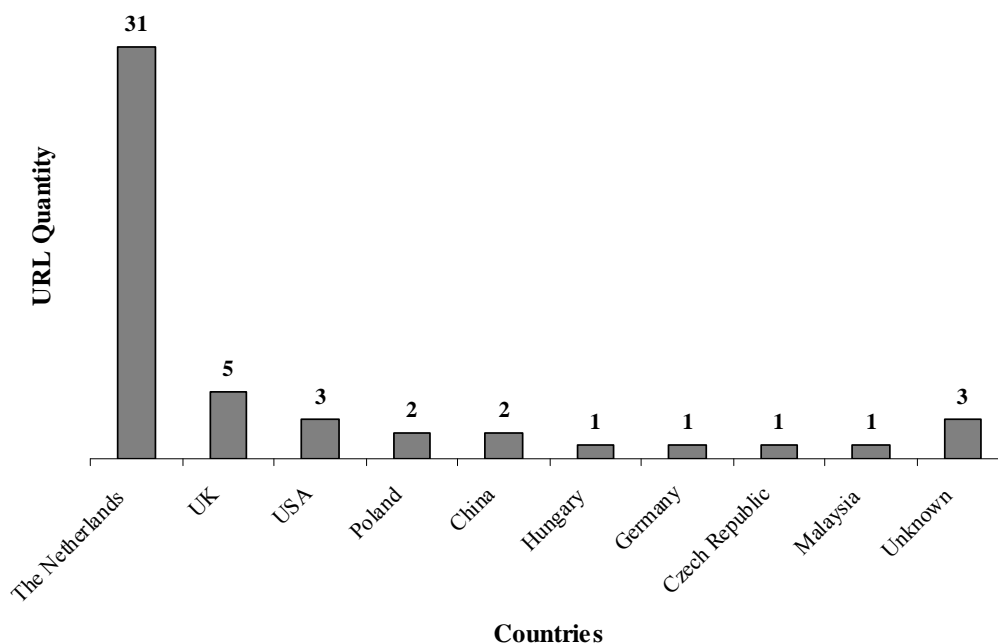
227 *3.1.1 Websites geolocation*

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

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

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

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



258

259

260

Figure 2: Geolocation of the GBL websites considering IP addresses

261

262

263 **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

264

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

268 3.1.2 Digital links

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

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

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

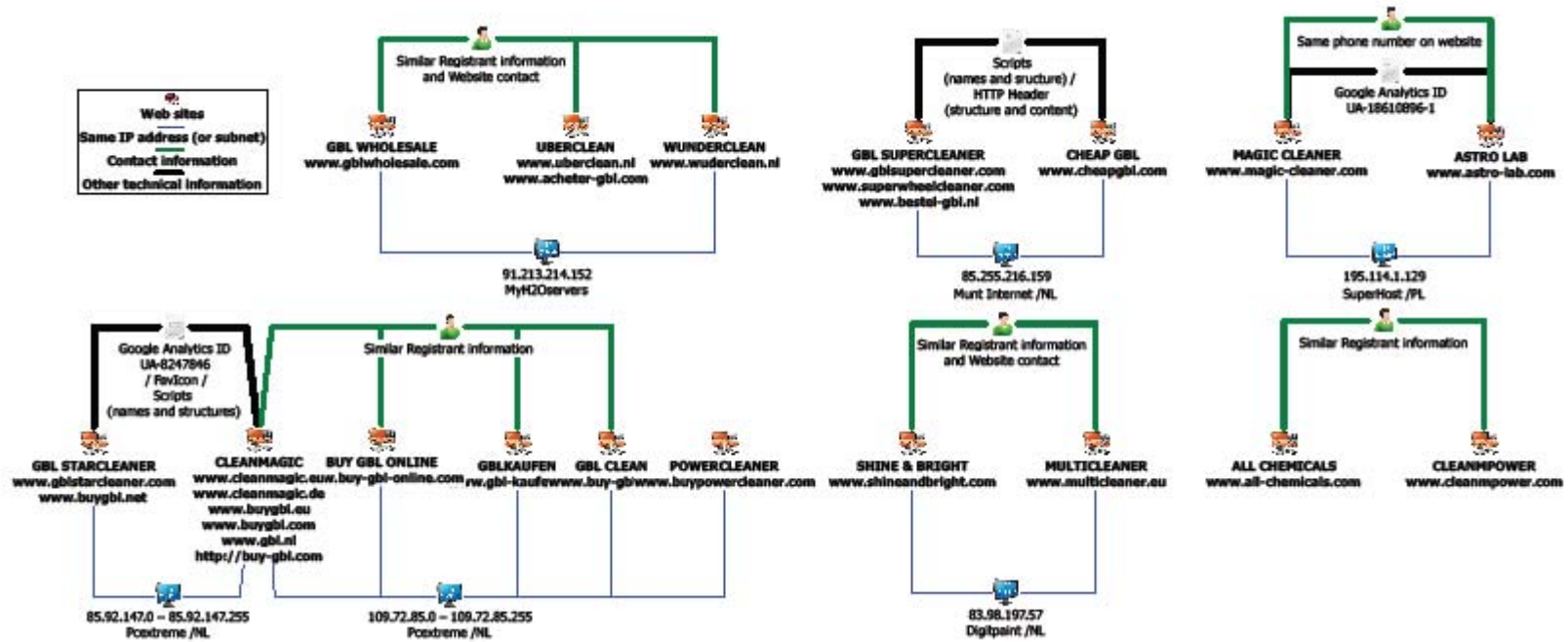


Figure 3: Schema showing all the GBL websites linked by digital information

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

296
 297 *3.2 Physical links: Packaging*

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

306 **Table 4:** Results of the obtained physical links
 307

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

308

309 *3.3 Determination of the chemical classes*

310 Carbon isotopic analyses were performed on twenty-five GBL specimens coming from
311 sixteen different websites as well as on eight GBL specimens coming from four alleged
312 producers. The results showed a wide variation of $\delta^{13}\text{C}$ -values ranging from -23.11‰ to -
313 45.74‰. Concerning the alleged Chinese GBL producers, the carbon isotopic values ranged
314 from -27.54‰ to -29.83‰. All the $\delta^{13}\text{C}$ -values were associated with very low standard
315 deviation (lower than 0.3‰) of triplicate analyses (**Table 5**).

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

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

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

Websites Names	Specimens	GBL origin	$\delta^{13}\text{C}$ -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	-

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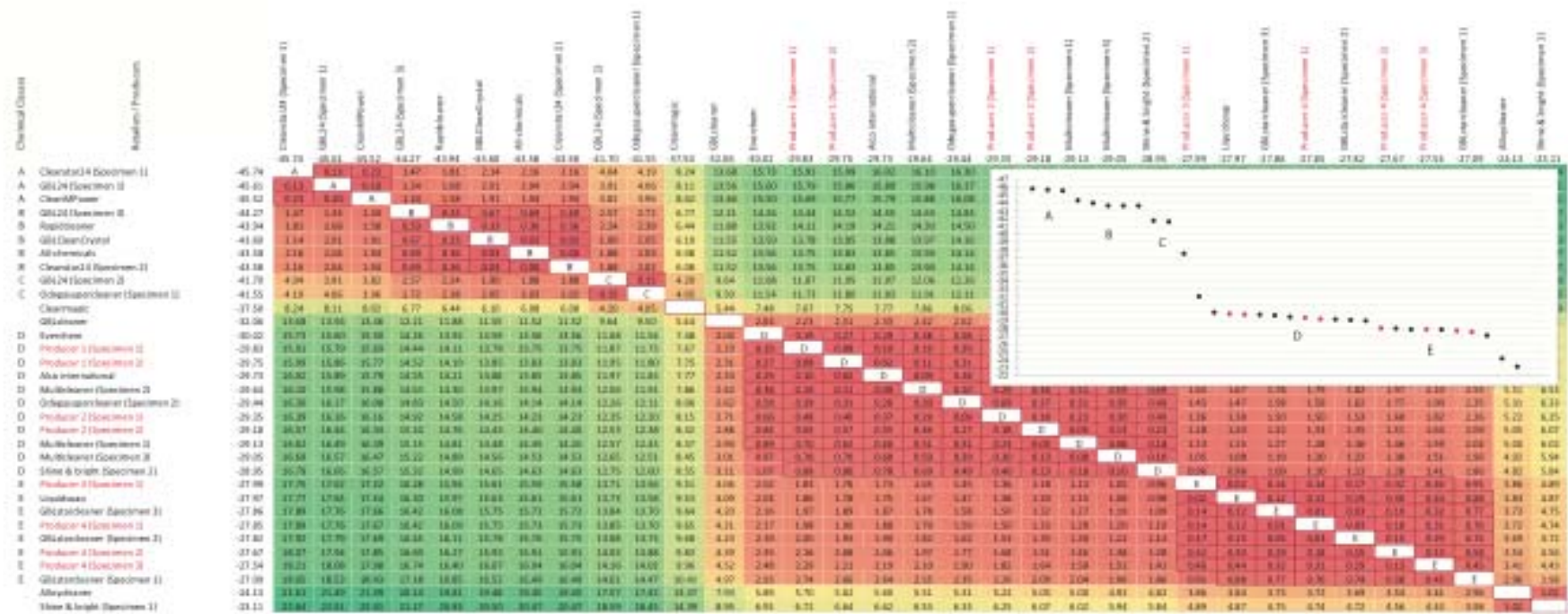
344 In fact, classes A, B and C correspond to GBL specimens originating from Germany and
 345 classes D and E are related to specimens originating from China. Likewise, Chinese
 346 specimens of class D can be related with Chinese producers 1 and 2 while GBL specimens of
 347 class E correspond to Chinese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

348 Based on previous work, it can be assumed that the wide range of carbon isotopic values
 349 obtained for GBL specimens is due to the synthetic pathways and the starting material
 350 employed. In fact, several chemical precursors may be potentially used for the manufacturing
 351 of GBL at an industrial level [12]. The major portion of GBL is currently produced from the
 352 dehydrogenation of 1,4 Butanediol (1,4-BD), which is manufactured via the REPPE process
 353 from the reaction of acetylene with formaldehyde [16]. Other GBL manufacturing processes
 354 are based on economically attractive raw chemicals such as maleic anhydride [17, 18] and
 355 dimethyl maleate [19] via the Davy process. Almost all companies manufacturing GBL in
 356 Europe use the REPPE process in their production chain whereas in Asia both REPPE and
 357 Davy processes are often used [14]. New eco-friendly manufacturing routes using the
 358 biotransformation of natural starting materials such as glucose have also emerged recently
 359 [20]. Therefore, it may be expected that specimens of classes A, B, C (German specimens)
 360 and classes D, E (Chinese specimens) were manufactured via different synthesis processes
 361 and different feedstocks. Concerning the small differences in the $\delta^{13}\text{C}$ -values between A, B
 362 and C as well as between D and E, it may be hypothesized that these specimens were
 363 manufactured through the same synthesis process but perhaps with different starting materials
 364 or different batches of the same starting material. This could explain the small differences in
 365 the $\delta^{13}\text{C}$ -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 $\delta^{13}\text{C}$ -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.

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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.

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377 *3.4 Combining digital, physical and chemical information*

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

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

420

425 **4. Conclusion**

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

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

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

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