

**STUDY OF LOSSES OF VOLATILE COMPOUNDS FROM DYNAMITES. INVESTIGATION
OF CROSS-CONTAMINATION BETWEEN DYNAMITES STORED IN POLYETHYLENE
BAGS**

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ABSTRACT

The purpose of this work was to study the appropriateness of polyethylene bags for the preservation of explosive specimens. To this end, specimens of two types of dynamites, Goma-2 EC, containing nitroglycol (EGDN) and dinitrotoluene (DNT), and Goma-2 ECO, containing only EGDN, were placed individually inside bags and introduced into hermetically sealed glass jars, which were stored for a period of time. Losses of volatile compounds were studied by headspace analysis using Gas Chromatography coupled to Mass Spectrometry (GC-MS). The cross-contamination between dynamites was studied by using High Performance Liquid Chromatography with Mass Spectrometry (HPLC-MS) to analyze the extracts obtained after a sequential solvent extraction of these specimens. Polyethylene bags permit the loss of volatile compounds since EGDN and DNT were detected in the headspaces of the jars. Moreover, cross-contamination between dynamites was also demonstrated since DNT content decreased in the dynamite containing this compound and increased in the dynamite that had not contained it.

Keywords

Forensic chemistry; Dynamite; Cross-contamination; Evidence container; Ethylene glycol dinitrate; Dinitrotoluene.

1. Introduction

Explosive specimens are of great importance in cases of terrorism, in which dynamites and other kinds of explosives may be used. There are many types of explosives, which differ in their composition, appearance, explosive capability or even place of manufacture. These characteristics of the explosives may be used to identify the explosive that was used in the perpetration of a crime. Moreover, due to the fact that terrorists often use a single type of explosive, usually obtained in a robbery, these characteristics may be decisive when determining the source of the explosives used and the authorship of the attack, or at least, to offer some orientation to a forensic investigation.

Goma-2 ECO and Goma-2 EC are Spanish-made high explosives (dynamites) intended primarily for industrial use, such as mining and demolition, or military applications. Goma-2 ECO is a gelatinous dynamite composed of EGDN, ammonium nitrate, nitrocellulose, dibutyl phthalate (DBP), calcium carbonate, and flour or sawdust. This high explosive has commonly been used in Spain and also exported abroad. Unlike Goma-2 EC, Goma-2 ECO was developed in line with European environment regulations [1] and does not contain the highly toxic compound DNT in its composition. Unlike Goma-2 ECO, Titadyn contains nitroglycerin (NG) and DNT in its formulation. In terms of their composition, Goma-2 ECO, Goma-2 EC, and Titadyn are heterogeneous materials.

Goma-2 ECO was allegedly used in the March 11 2004 train bombings in Madrid (Spain). The authorship of the attack has not yet been clarified, the controversy still lingering today. At first, responsibility was assigned to ETA (the Basque terrorist organization); however, this organization denied any connection with these attacks while the organization Al-Qaeda later acknowledged its responsibility for the outrage. ETA has used Titadyn repeatedly in terrorist attacks. Since trace amounts of NG and DNT were detected in some of the explosive evidences of the 11 March blast, the possibility ETA authorship was placed back on the table. Pursuant to the action protocol, explosive evidences collected at the scene of the bombings were put into official polyethylene bags and transported to a laboratory where many other explosives were kept. For this reason, the possibility that there might have been contamination between different specimens was considered.

Cross-contamination occurs when certain compounds are transferred from one specimen to another [2]. It can take place between very different kinds of specimens and, if not detected, always leads to erroneous results in scientific studies. In forensic investigations, contamination between specimens as a result of incorrect preservation may lead to charging or arresting innocent people. Therefore, it is important to pay special attention when handling, sampling and storing specimens of explosive in order to avoid cross-contamination and incorrect interpretation of forensic cases.

Contamination between explosive specimens may occur through physical contact with contaminated surfaces, with other specimens or with particles or vapors. In fact, the contamination of explosives by vapors is possible because highly volatile compounds, such as EGDN, NG or DNT are usually present in many explosives. The vapor pressure of a given compound measures its capacity of volatilization; in general, the higher the vapor pressure, the higher the capacity of volatilization and the lower the capacity to be retained by certain materials. EGDN has the highest vapor pressure (7.0×10^{-2} torr at 25°C), followed by DNT and NG (2.0×10^{-3} and 2.3×10^{-4} torr at 25°C , respectively) [3]. Contamination by vapors is also dependent on the adsorption characteristics of the compounds, which are defined by their affinity with the material [4]. These compounds may exhibit a very strong affinity to be adsorbed on a variety of materials such as hair [3], charcoal [5], organic matter from soil [6], other components of soils like sands or clays [7-9] and some polymers [10, 11]; in most cases adsorption may occur in an almost irreversible manner [4]. In fact, volatile compounds may bind easily to porous materials with a high surface-area-to-volume ratio. It should be stressed that nowadays, adsorbent porous materials such as calcium carbonate are used as components of explosives.

As far as we know, there have been very few studies of the loss of volatile compounds due to the material of the container used for storing the specimens in the field of forensics [12-15]. Those studies that exist mainly focus on the capability of fire debris evidence receptacles to avoid the loss of vapors. However, both for fire debris and for specimens of explosives the objective is the same: to avoid the loss of volatile compounds and to prevent changes in the specimens. For this reason, the same containers used for specimens of fire debris can be used for specimens of explosives and their characteristics are similar. When dealing with specimens

of fire debris the containers recommended are metal "paint" cans with compression lids, glass mason jars with standard pressure-canning flats and bands, and special polymer sample bags [15-18]. However, each type of container has its advantages and disadvantages and care must be taken when choosing the containers to be used for specimen storage. For example, containers made of glass are usually big and their handling and transport requires special care because they are fragile. On the other hand, they are very simple to use and can be closed easily by screwing the tops of the jars. This is an advantage not shared by polyethylene bags. These are tough and not liable to breakage, but their handling is often complicated and great care is required when sealing the bag in order to ensure that there are no poorly closed segments that may allow the output of volatile compounds. Although the size, robustness and ease of use of containers are very important issues, when choosing a suitable container perhaps more importance should be attached to the capacity of containers to prevent loss of volatile compounds. Nowadays, polymer bags are being used to preserve explosive specimens because they are considered the best system to avoid vapor losses in comparison with metal paint cans and glass mason jars; however, these bags are not fully efficient and may allow losses of trace amounts of volatile compounds in specimens of fire debris [15]. In fact, recent discussion of the quality of the methods for sampling and preserving explosive specimens and other volatile substances in forensic laboratories [12-15] has led to the conclusion that current procedures are unsuitable or do not ensure the proper preservation of specimens [12, 14, 15]. This represents a huge problem that must always be borne in mind when interpreting the results of a forensic case. Some authors have developed and tested sampling kits for the collection of evidences as alternatives to those currently used [12], paying special attention to avoiding contact between the specimen and the walls of the container.

This work aimed, firstly, to study the dynamics of the loss of the highly volatile EGDN from Goma-2 ECO dynamite under different temperature and time conditions; and, secondly, to evaluate whether the official polyethylene bags used by the Spanish Security Forces to transport and store specimens are suitable systems. For this latter purpose, the chances of losses occurring of volatile components (specifically, EGDN and DNT), as well as of cross-contamination occurring between different dynamite specimens kept in the official bags and stored together in a confined space, were investigated.

2. Material and methods

2.1 Chemicals and materials

The extraction of EDGN and DNT was carried out with ultrapure water (18.2 Ω) from a Millipore Milli-Q water system (Bedford, MA, USA) and HPLC-grade methanol purchased from Sigma-Aldrich (St. Louis, MO, USA). Mobile phases for HPLC were also prepared with Milli-Q water and HPLC-grade methanol. 2,4-DNT, 2,6-DNT, 3,4-DNT, and EDGN standards (1 $\mu\text{g/mL}$) were supplied by Restek Co. (Bellefonte, PA, USA).

Specimens of Goma-2 ECO dynamite were kindly donated by MaxamCorp Holding, S.L. (Madrid, Spain). Specimens of Goma-2 EC dynamite were provided by the Criminalistics Service of the Guardia Civil (Madrid, Spain). The composition of these specimens, together with that of another high explosive (Titadyn), is shown in **Table 1**.

The official plastic bags used by Spanish Security Forces to transport and to store evidence specimens in forensic cases were provided by the Criminalistics Service of the Guardia Civil. These bags, supplied by Royal Pack, S.L. (Alcalá de Henares, Spain), are made from polyethylene and have a rubber sealing that prevents the output and input of gases.

2.2 Instrumentation

HPLC analyses of the extracts of dynamites were performed in a fully equipped, Agilent series 1100 liquid chromatograph (Pittsburgh, PA, USA) with a diode-array detector (DAD) and an atmospheric pressure chemical ionization (APCI) mass spectrometer (MS) detector (HPLC-DAD-MS). The separation was performed in an ODS ProntoSIL Hypersorb column (250 x 4.6 mm i.d.; 5.0 μm particle diameter) from Scharlab S.L. (Barcelona, Spain). The separation method used consisted in one-step gradient from 25% to 95% B in 35 min, using a temperature of 40 $^{\circ}\text{C}$. The mobile phases were water (mobile phase A) and methanol (mobile phase B); the flow-rate was 1 mL/min and the injection volume was 10 μL . UV detection at 230 nm as analytical wavelength (4 nm bandwidth) and 550 nm as reference wavelength was employed. For APCI, the instrumental conditions were: nebulizer pressure 40 psi; drying gas (N_2) at a flow-rate of 4 L/min; drying gas temperature at 350 $^{\circ}\text{C}$; vaporizer temperature at 325 $^{\circ}\text{C}$; negative scan in the range $m/z = 100\text{--}650$; Vcap (positive) at 4000 V; Vcap (negative) at 1500 V; corona

(positive) at 4 μA ; and corona (negative) at 10 μA . Every specimen solution was injected by triplicate in the chromatographic system. Data were captured and processed using the LC-MSD ChemStation Software (Agilent Technologies) software package.

Gas chromatography coupled with mass spectrometry experiments to study volatile compounds in the headspaces of the glass jars were performed in an Agilent 7000A Triple Quad GC/MS (Pittsburgh, PA, USA). 0.1 μL of headspace specimens from each jar was collected employing a solid-phase micro-extraction fiber (75 μm CarboxenTM PDMS) and was injected at 250 $^{\circ}\text{C}$ with an Agilent 7683B injector (Pittsburgh, PA, USA) working in a pulsed splitless mode (at 6.5054 psi). Gas chromatography analysis was carried out with an Agilent 7890A (Pittsburgh, PA, USA) gas chromatograph with helium as the carrier gas and a HP-5MS (5 % Phenyl Methyl Siloxane) 30 m x 250 μm x 0.25 μm column, initially kept at 325 $^{\circ}\text{C}$. The separation method used consisted in a five-step gradient from 50 $^{\circ}\text{C}$ to 260 $^{\circ}\text{C}$ over 42 min: first, 50 $^{\circ}\text{C}$ for 3 min; second, an increase of 2 $^{\circ}\text{C}/\text{min}$ to 70 $^{\circ}\text{C}$; third, an increase of 4 $^{\circ}\text{C}/\text{min}$ to 130 $^{\circ}\text{C}$; fourth, 130 $^{\circ}\text{C}$ for 1 min; and fifthly, an increase of 10 $^{\circ}\text{C}/\text{min}$ to 260 $^{\circ}\text{C}$. The flow-rate was 0.9 mL/min. Mass spectrometry detection was carried out using an Agilent 7000 A triple quadrupole mass spectrometer (Pittsburgh, PA, USA) operating in electronic impact mode. The temperature at 230 $^{\circ}\text{C}$, electron energy at 70 eV, electron multiplier voltage at 1449.0 V and scan in the range $m/z = 30\text{--}550$ over 260 ms, were used. Data were acquired and processed using the Agilent Masshunter version B.05.00.412 software (Agilent Technologies).

EGDN and DNT isomers in the chromatograms were identified by comparing the retention times of peaks in the chromatograms of the specimens with those for EGDN, 2,4-DNT, 2,6-DNT, and 3,4-DNT standards.

Specimens were weighed using a MC210P balance (Sartorius, Göttingen, Germany) with an accuracy of $\pm 10 \mu\text{g}$ and a precision of $\pm 20 \mu\text{g}$. Solutions were prepared in an ultrasonic bath ULTRASONS-H (JP Selecta, Barcelona, Spain).

2.3 Experimental procedure

The dynamics of EGDN loss from Goma-2 ECO dynamite stored in plastic bags were tested in three parallel studies. In the first, a short-term study, six specimens of Goma-2 ECO dynamite, each weighing 6 g, were placed in official hermetic polyethylene bags that were

properly closed. Then each bag with its specimen of Goma-2 ECO dynamite was placed in a glass jar special for GC. The jars were stored at room temperature for 24 days in a cupboard and 2 specimen analyses per week were done. In the second, a temperature study, specimens were prepared as described above and jars were stored at 60 °C for 24 days performing 2 analyses per week. For the third study, a long-term study, 34 specimens of Goma-2 ECO dynamite, each weighing 1.5 g were put into official bags, which were sealed and stored for 121 days at room temperature in a cupboard. EGDN content (%) in the different specimens was monitored as a function of time (~9 specimens analyses per month). To this end, the bags were opened one by one and the EGDN remaining in Goma-2 ECO dynamite was extracted as per the extraction method developed by Sáiz et al. [19] and analyzed by HPLC-DAD-MS. Briefly, 0.1 g of dynamite specimen was sequentially extracted with Milli-Q water and methanol (twice, 10 mL of solvent, sonication during 5 min, and adjustment of the two extracted phases with the same solvent to a final volume of 25 mL). Aqueous and methanolic extracts were finally analyzed in triplicate by HPLC-DAD-MS. The final concentration of EGDN in the specimen was calculated as the sum of EGDN concentrations in the methanolic and water extracts.

To study the loss of volatile compounds (EGDN and DNT) from two different dynamites (Goma-2 EC and Goma-2 ECO) stored at room temperature in plastic bags, eight specimens of Goma-2 EC dynamite and eight specimens of Goma-2 ECO dynamite of 0.25 g were weighed and put into one official plastic bag for transportation and storage of evidence specimens. Plastic bags were distributed by pairs, one containing Goma-2 EC dynamite and the other one containing Goma-2 ECO dynamite, into special glass jars for GC; a piece of paper was put between bags to avoid physical contact (see **Figure 1**). Because the plastic bags were larger than the jars, they were folded before being placed inside them. The jars were stored for a maximum period of 28 days. Every seven days the headspaces of two jars were analyzed by GC-MS in order to determine the presence of volatile components from the explosives. After the analysis of vapors by GC-MS, the solid dynamite specimens were removed for the extraction of EGDN using the method explained above. Finally, aqueous and methanolic extracts were analyzed in triplicate by HPLC-DAD-MS in order to evaluate cross-contamination between explosive specimens kept in official plastic bags and stored in the same place.

The limit of detection (LOD) of the GC-MS, HPLC-DAD and HPLC-MS systems was calculated for a signal-to-noise ratio (S/N) of 3:1. For this study, nine standard solutions of 2,6-DNT in methanol (2000 ng/mL, 1000 ng/mL, 500 ng/mL, 300 ng/mL, 100 ng/mL, 60 ng/mL, 12 ng/mL, 6 ng/mL, and 3 ng/mL) were injected into the chromatographic systems. The lowest concentration was used to calculate the LOD value.

3. Results and discussion

3.1 Study of the dynamics of EGDN loss from Goma-2 ECO during the storage of the dynamite

This study was devised in order to achieve a better understanding of the dynamics of the volatilization of EGDN from explosive materials, more specifically, Goma-2 ECO dynamite. As can be seen in **Figure 2**, this study offers evidence that the loss of EGDN from the dynamite studied was progressive over time. In the short-term study and the long-term study performed at room temperature, the behavior of EGDN loss as a function of time was very similar: EGDN content diminished in a square-root-like way, according to the equations of the models that best fitted the experimental data (**Table 2**). It is worth noting that after approximately one month of storage, nearly 30% of this dynamite's EGDN content was lost, a figure which increased to 66% in two months. As is to be expected, in the short-term study carried out at higher temperature, a drastic loss of EGDN over time was observed (the square-root decay with time of EGDN content was, approximately, three times higher than in the previous studies). From all these data we may conclude that the EGDN content of Goma-2 ECO diminished substantially during the storage of this dynamite in a polymeric bag, at room temperature, the main reason for this being the easy diffusion of this compound through the pores of the packaging and its subsequent loss in the environment.

3.2 Study of losses of volatile compounds (EGDN and DNT) from two different dynamites stored in official plastic bags

The volatilization of both EGDN and DNT contained in two dynamites put into the official polyethylene bags used by the Spanish Security Forces to transport and store evidence specimens has been investigated. This study involves, firstly the analysis, at different times, of EGDN and DNT in the headspace of the jars containing the bags and, secondly, the determination of the EGDN concentration remaining in the dynamites. **Figure 3** shows the

chromatogram corresponding to the headspace of one glass jar, analyzed after one week of storage. It shows the peaks corresponding to EGDN and two isomers of DNT (2,6-DNT and 2,4-DNT). It is interesting to note that the LOD for DNT, to be precise, for the 2,6-DNT isomer, is 1.0 mg/mL, while the concentration of DNT isomers detected in the headspace of the jars is much higher than the LOD concentration. According to these results, these storage bags allow the quick loss of volatile compounds. This leads to changes in the composition of the specimen during its storage time and may give rise to serious errors in the interpretation of the results obtained from explosive specimens in a given forensic case. Although the mechanism by which these volatile compounds are lost from the bags remains unclear, the main causes of this process may be the sealed areas of the bags and/or the pores in the polyethylene polymer bags. However that might be, this study demonstrates that the use of polyethylene bags for the transport and storage of explosive evidence requires stringent oversight if cross-contamination due to volatile components is to be avoided.

3.3 Study of cross-contamination between explosive evidence stored in official plastic bags in a common space

This study has considered three different dynamites (Goma-2 ECO, Goma-2 EC, and Titadyn), which differed in their volatile components. According to **Table 1**, a component common to all of them is EGDN. Goma-2 EC and Titadyn also have DNT in common, while only Titadyn contains NG. Since DNT is present in Goma-2 EC dynamite but not in Goma-2 ECO dynamite, the presence of DNT in this last dynamite was studied to evaluate the possibility of cross-contamination between these two dynamites. However, at the time of the study, dynamites containing both DNT and NG in their composition (like Titadyn, see **Table 1** for further information) were not available. As a consequence, Goma-2 ECO and Goma-2 EC dynamites were placed in polyethylene bags stored in the confined space provided by glass jars hermetically closed. The evolution of EGDN and DNT content in both specimens over time was monitored by extracting these components with methanol and water, as described by Sáiz et al. [19], and analyzing them by means of HPLC.

First of all, a comparison of the sensitivity of the two detection systems in HPLC was carried out to determine which was the better suited to detecting trace amounts of DNT. For DAD detection, the LOD for 2,6-DNT, the isomer mainly detected, were 300 ng/mL while, for

MS detection, the LOD corresponding to 2,6-DNT was lower than 3 ng/mL; in other words, MS detection permitted the detection of concentrations more than 2 orders of magnitude lower than DAD detection. Next, HPLC-MS was selected for the analysis of the extracts. The highest peak areas of volatile compounds in the extracts were always found in the methanolic phases, while their concentration in water was almost negligible. As a consequence, the methanolic extracts obtained by the extraction method were injected into the HPLC-MS system.

Figure 4 shows the chromatograms obtained for the methanolic extracts of Goma-2 ECO dynamites before starting the study (**Figure 4a**) and after one, two, three, and four weeks of storage in the conditions described above (**Figure 4b-e**). Curiously, in **Figure 4a**, the chromatographic peaks of DNT, close to the LOD (3 ng/mL), were observed. This means that Goma-2 ECO specimens were contaminated before starting the study with trace amounts of DNT. For this reason, contamination should not be attributed only to the laboratory atmosphere because the specimens had been stored in the glass jars as soon as they had been received in the laboratory. The contamination probably begins during the manufacturing process of the explosive. This hypothesis was supported by two facts: the same reactors were used to make both Goma-2 EC and Goma-2 ECO dynamites; and cross-contamination during the storage of the dynamites in the warehouse must not be disregarded.

On the other hand, **Figure 4** also shows how DNT peak areas in Goma-2 ECO dynamite grew over storage time. This implies that some transference of DNT from Goma-2 EC to Goma-2 ECO specimens occurred. Hypothetically, this transfer could occur in three stages. The first could be the volatilization of DNT from Goma-2 EC dynamite and its output through the plastic bag where it is kept in to the common space (jar compartment). The second stage could be the entrance of DNT into the interior of the bag containing the Goma-2 ECO dynamite. Finally, DNT could be retained by this dynamite, either by adsorption or some other process, given the strong affinity of this material towards volatile compounds.

Figure 5 shows the evolution of DNT peak areas (calculated as the sum of the total DNT peak areas corresponding to 2,4-DNT, 2,6-DNT, and 3,4-DNT isomers in the aqueous and in the methanolic phases) in Goma-2 ECO and Goma-2 EC specimens. An increase in DNT peak areas in Goma-2 ECO dynamite to the detriment of the DNT peak areas in Goma-2 EC

dynamite was observed. Furthermore, the DNT peak area in Goma-2 ECO and in Goma-2 EC dynamites reached a stationary state in which Goma-2 ECO seemed unable to retain more DNT while Goma-2 EC seemed to stop the DNT loss. Meanwhile, the high standard deviation values obtained for the two individual specimens analyzed (each by triplicate) may be explained because: a) it is impossible to standardize the manipulation of the bags, the different folding of each of which affected the area of the bag exposed to the environment and the contact area of the dynamite with the bag; b) the heterogeneity of the specimens, which affects the amount of DNT in Goma-2 EC specimens and the capacity to absorb DNT by Goma-2 ECO dynamite; and c) the DNT content in Goma-2 ECO dynamite measured during the study was 2-3 orders of magnitude smaller than that measured in Goma-2 EC dynamite, thus leading to higher relative standard deviation values for Goma-2 ECO in comparison with Goma-2 EC.

The results obtained in this work demonstrate that polyethylene bags used by Spanish Security Forces are not ideal systems for transporting and storing explosive specimens because they do not offer a physical barrier for some volatile molecules present in explosives, which can enter and leave the bags easily. In addition, the high capacity of other explosive materials to retain these molecules is a significant factor. Therefore, the chances of cross-contamination between explosive specimens stored in polythene bags in a common space are very high in a short period of time.

The evidence specimens of the March 11 train bombings were stored in polyethylene bags together many other explosives, such as Titadyn or other dynamites containing NG and DNT, for 3 years before their analysis. Given that the quantities of both NG and DNT found in the Goma-2 ECO specimens in this forensic case were several orders of magnitude smaller than those found in other dynamites, and due to the other dynamites were stored in the same laboratory, the possibility that there was contamination between the specimens during the storage time should be seriously considered.

4. Conclusions

In this work the capacity of the polyethylene bags used by the Spanish Security Forces to preserve explosive evidences has been investigated. GC-MS results showed that the volatilization of EGDN and DNT from dynamites occurs gradually over time, happening faster at

higher temperatures. The mechanism by which these volatile molecules may leave the bags is still unclear and further investigations are needed.

In addition, the results obtained by HPLC-DAD-MS demonstrated cross-contamination of volatile compounds between dynamites stored in the same small closed space. In fact, DNT was found in Goma-2 ECO dynamite while simultaneously the concentration of this compound decreased in Goma-2 EC dynamite. This process continues over the storage time until a stationary state is achieved. As a result, this work demonstrates that:

- i) Polyethylene bags are not ideal for transporting and storing specimens of explosives at room temperature. Since the volatilization process diminishes at low temperatures, the storage of explosive specimens in refrigerated chambers or refrigerators is recommended. Another solution could be the substitution of bags by other kinds of packaging containers;
- ii) Cross-contamination, which has an important impact on the interpretation of results, should be taking into account when explosive specimens have been stored in the same room at room temperature;
- iii) Further studies are required to collect information about the loss of volatile compounds under the proposed conditions.

Abbreviations used

EGDN, ethylene glycol dinitrate; NG, nitroglycerine; DNT, dinitrotoluene; DBP, dibutyl phthalate; HPLC, high performance liquid chromatography; DAD, diode array detection; APCI, *atmospheric pressure chemical ionization*; MS, mass spectrometry; HPLC-DAD-MS, *high performance liquid chromatography* with diode-array detection and coupled to mass spectrometry detection; GC, gas chromatography; GC-MS, gas chromatography coupled to mass spectrometry detection; *LOD*, *limit of detection*; *S/N*, *signal-to-noise ratio*.

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Figure Captions

Figure 1. A) Goma-2 EC dynamite; B) Goma-2 ECO dynamite; C) Official plastic bags used by the Spanish Security Forces to transport and store specimens that are intended for forensic analysis; D) Diagram showing the experimental setup designed to study the losses of volatile compounds from polyethylene bags and the cross-contamination between dynamite specimens. Specimens of Goma-2 ECO (a) and Goma-2 EC (b) dynamites were introduced into official polyethylene bags (c) which were properly closed. They were placed in a glass jar for GC (d) separated by a piece of paper (e) and the glass jar was properly closed.

Figure 2. Evolution over time of EGDN content (%) in specimens of Goma-2 ECO stored in polyethylene bags. (a) Long-term study during 121 days at room temperature, (b) short-term study during 24 days at room temperature, (c) temperature study during 24 days at 60 °C.

Figure 3. GC-MS chromatogram of the headspace of a jar containing one polyethylene bag with a specimen of Goma-2 ECO and one polyethylene bag with a specimen of Goma-2 EC, after one week of storage. DNT, dinitrotoluene.

Figure 4. HPLC chromatograms of methanolic extracts of Goma-2 ECO specimens (a) before starting the study and after (b) one, (c) two, (d) three, and (e) four weeks of storage in polyethylene bags kept in hermetically closed glass jars containing also Goma-2 EC in polyethylene bags. DNT, dinitrotoluene.

Figure 5. Averages and standard deviations of DNT peak areas (sum of the total DNT areas corresponding to 2,4-DNT, 2,6-DNT, and 3,4-DNT isomers in the aqueous and methanolic extracts obtained from dynamites) in the dynamites stored during one, two, three, and four weeks in a common place (jars).

Figure 1.

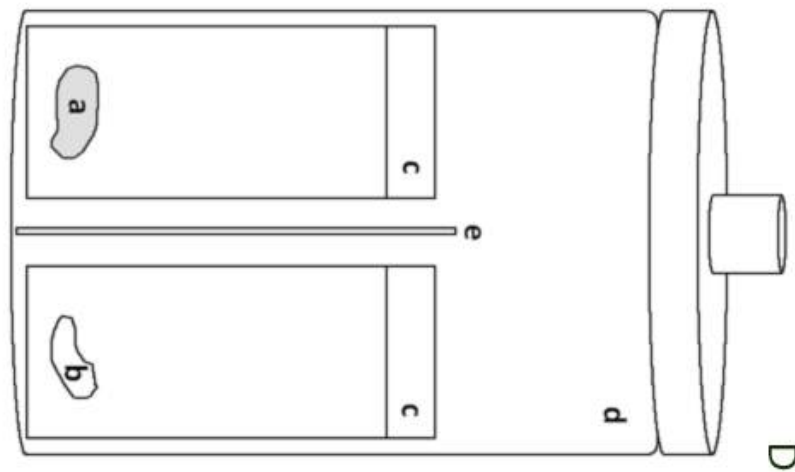


Figure 2.

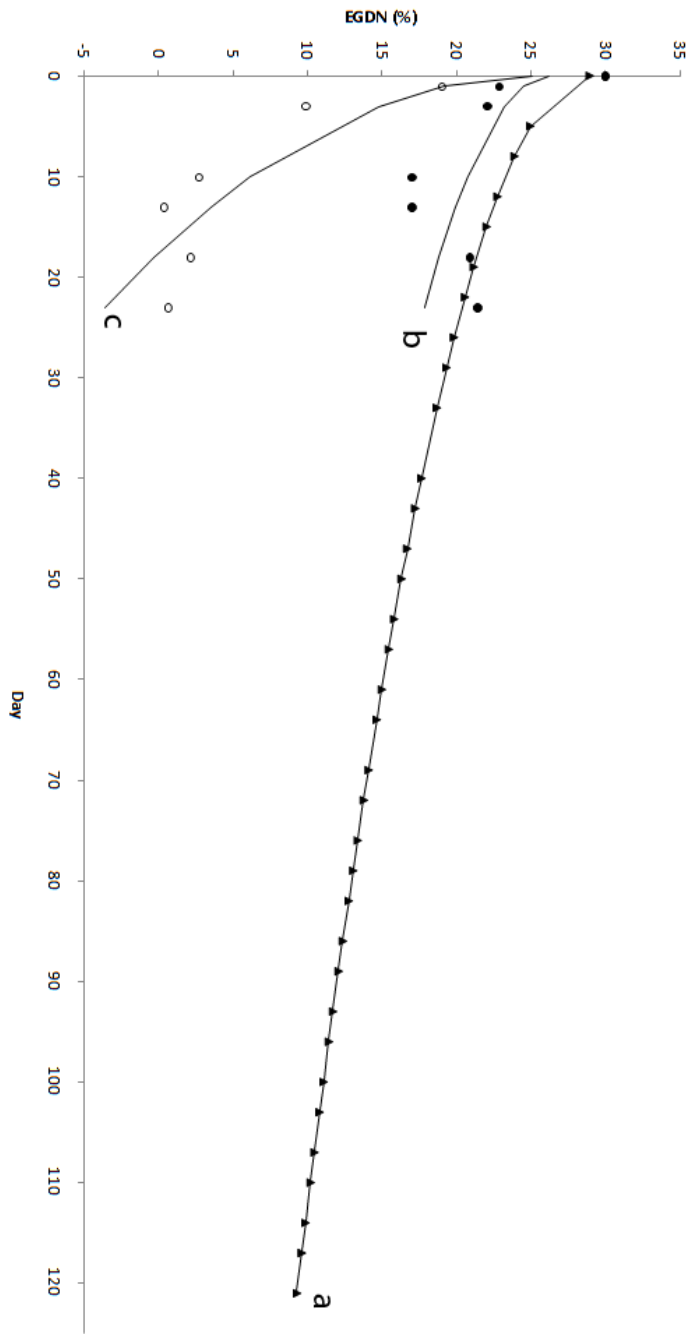


Figure 3.

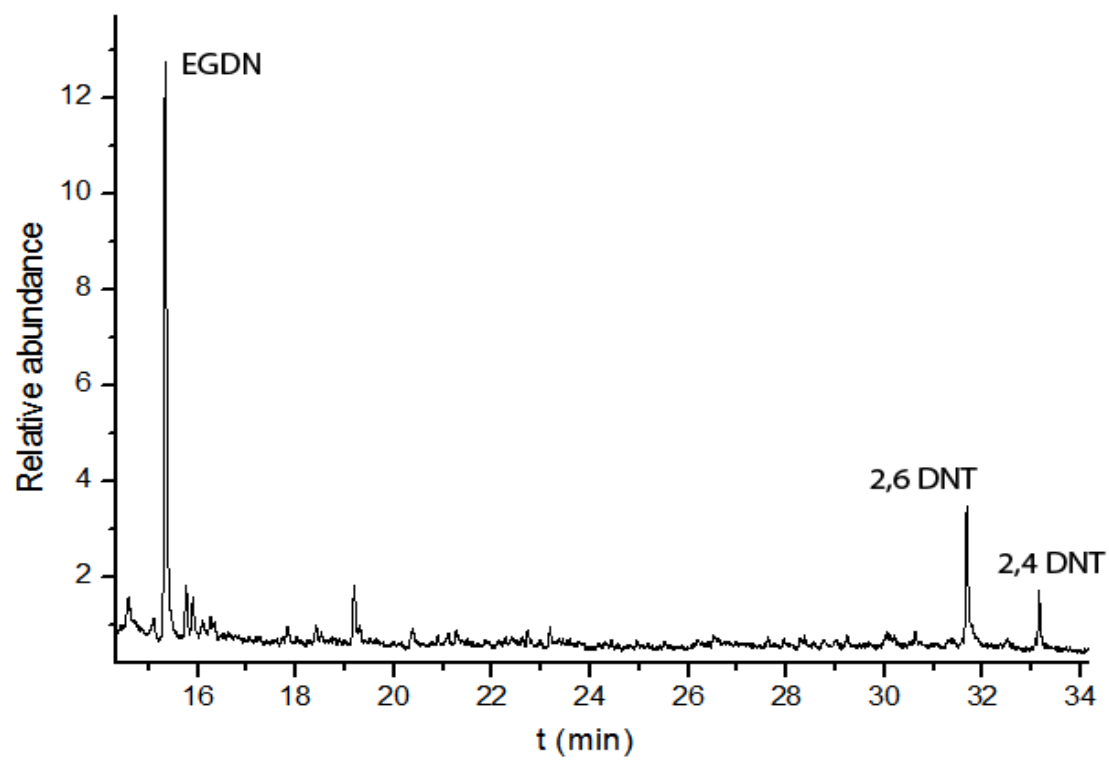


Figure 4.

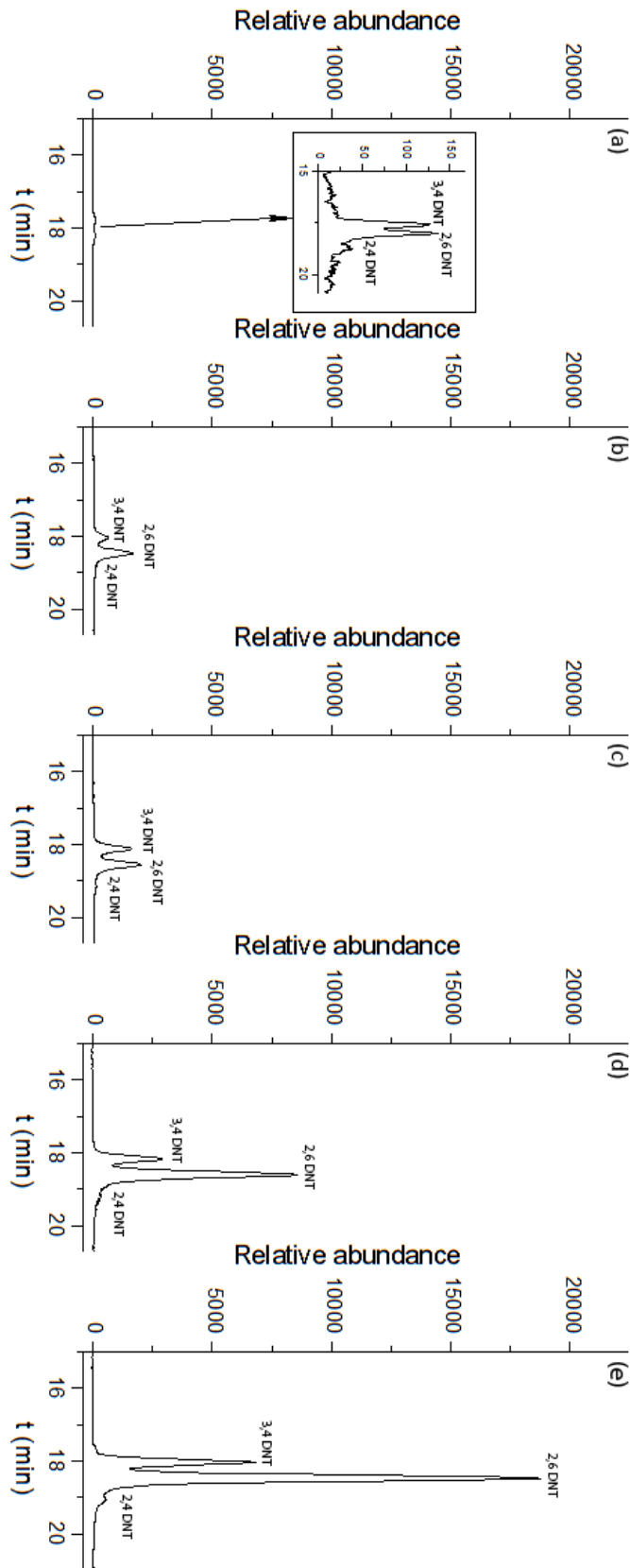


Figure 5.

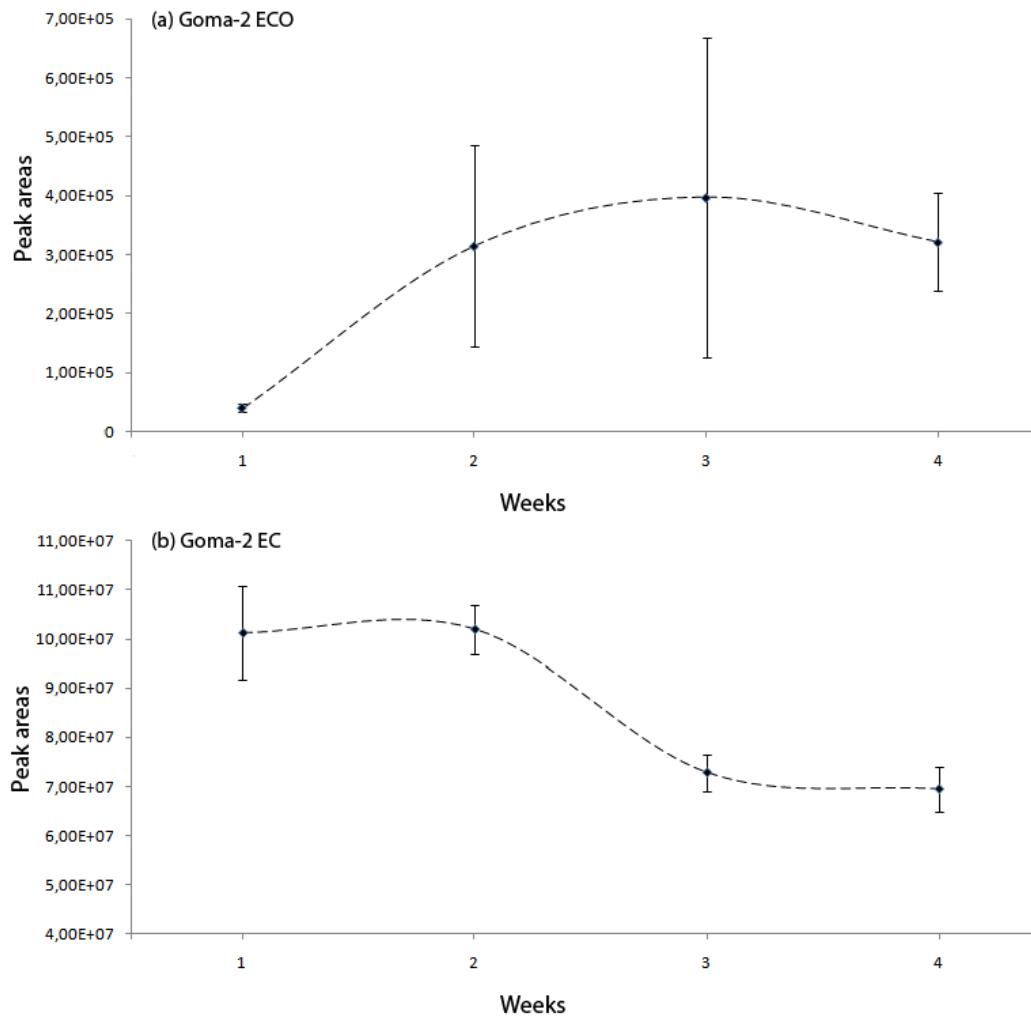


Table 1. Composition, indicated by the manufacturer, of high explosives Goma-2 ECO, Goma-2 EC and Titadyn.

	Goma-2 ECO	Goma-2 EC	Titadyn
EGDN	✓	✓	✓
NG			✓
DNT		✓	✓
Nitrocellulose	✓	✓	✓
Ammonium nitrate	✓	✓	✓
DBP	✓		
Calcium carbonate	✓		
Flour/sawdust	✓		

Table 2. Best fitted equations to describe the loss of EGDN from a dynamite Goma-2 ECO.

Study	Mathematical model	Correlation
Short-term study (room temperature)	$EGDN\ lost\ (\%) = 26.26 - 1.74 \times \sqrt{t\ (days)}$	-0.7079
Long-term study (room temperature)	$EGDN\ lost\ (\%) = 28.97 - 1.79 \times \sqrt{t\ (days)}$	-0.9377
Short-term study (60 °C)	$EGDN\ lost\ (\%) = 25.14 - 5.99 \times \sqrt{t\ (days)}$	-0.9359