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CASE REPORT

CRIMINALISTICS

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The Identification of Two Unusual Types of Homemade Ammunition*

ABSTRACT: Illegal homemade ammunition is commonly used by criminals to commit crimes in Taiwan. Two unusual types of homemade ammunition that most closely resembling genuine ammunition are studied here. Their genuine counterparts are studied as the control samples for the purpose of comparison. Unfired ammunition is disassembled, and the morphological, dimensional, and compositional features of the bullet and cartridge case are examined. Statistical tests are employed to distinguish the dimensional differences between homemade and genuine ammunitions. Manufacturing marks on head stamps of the cartridge case are carefully examined. Compositional features of propellant powders, primer mixtures, and gunshot residues are also analyzed. The results reveal that the morphological, dimensional, and compositional features of major parts of the ammunition can be employed to differentiate homemade cartridges from genuine ones. Among these features, tool marks on the head stamps left by the bunter can be used to trace the origin of ammunition.

KEYWORDS: forensic science, firearms examination, homemade ammunition, elemental analysis, gunshot residues, scanning electron microscopy/energy dispersive X-ray spectrometry

The criminal use of improvised or converted firearms is a common problem in some countries (1–3). It is not unusual for these homemade weapons to be used to inflict fatal gunshot wounds (4–7). Similar to other countries that have rigorous legislation on firearms control, a mere possession without any criminal use of unlicensed firearms is a criminal violation in Taiwan. Thus, in addition to the examination of fired bullets and cartridge cases, the identification of unfired firearms and ammunition is an important task for forensic firearms examiners. In Taiwan, because it is very difficult to obtain industrially manufactured firearms and ammunition, and because the penalty for illegal possession of homemade firearms is lighter than that of genuine firearms, criminals use homemade firearms and ammunition as substitutes when committing crimes (8). There is a wide variety of homemade ammunition commonly seized by local police forces. Most homemade ammunition is improvised or converted from legally available toy ammunition and can thus be easily differentiated from genuine ammunition in terms of size, weight, shape, color, and head stamps. However, among the various types of homemade ammunition, two unusual types of homemade ammunition confiscated in two criminal cases most closely resemble genuine industrially manufactured ammunition. They are indistinguishable from genuine ammunition for the first glimpse, but they can be discerned by firearms experts through an examination of their forensic features. They pose a substantial threat to society because they are illegal live ammunitions that can be discharged through real guns with regular calibers. In one case, officers of Tai-Chung City Police Bureau arrested a drug dealer wanted by the law. The police confiscated not only illicit drugs but also 18 rounds of illegal cartridges during the search of the criminal's residence. In another case, Chia-Yi City Police force seized one unlicensed pistol and 45 rounds of illegal cartridges while conducting a location search authorized by a search warrant. The seized ammunition from these two cases having head stamps of either "AP 03 9 MM LUGER" or "WIN 9 mm LUOER" were submitted to our department for identification. We suspected that these cartridges are homemade ammunition rather than industrially manufactured cartridges in the beginning. Further investigation of their forensic characteristics that proved our suspicion is described in this report. We have systematically studied the four major parts of these cartridges, namely, the bullets, cartridge cases, propellants, and primers. It is hoped that the results will help firearms experts in their identification of homemade ammunition and the interpretation of their findings in court.

Materials and Methods

Research Equipments

- Hitachi S-3400N scanning electron microscope (SEM) (Hitachi High-Technologies Corporation, Tokyo, Japan) combined with HORIBA EMAX-ENERGY energy dispersive X-ray spectrometer (EDS) (HORIBA Ltd., Kyoto, Japan).
- Hitachi Carbon Coating Unit.
- Leica DMC comparison microscope (Leica Mikroskopie und Systeme GmbH, Wetzlar, Germany) with Nikon E995 digital camera (Nikon Corporation, Tokyo, Japan).
- Perkin Elmer Spectrum GX-2000 Fourier transform infrared spectrometer (FT-IR) (PerkinElmer Inc., Waltham, MA).
- Mitutoyo Caliper (Mitutoyo Corporation, Kanagawa-ken, Japan).

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- METTLER TOLEDO PG6002-S balance (Mettler-Toledo (Schweiz) GmbH, Greifensee, Switzerland).
- Beretta Model 92 FS 9 mm Luger semi-automatic pistol (Fabbrica d'Armi Pietro Beretta, Brescia, Italy).

Research Materials

Two types of 9-mm Luger homemade ammunition with different head stamps were examined in this study. Seven rounds of each type of homemade ammunition were randomly selected and then disassembled and examined for their forensic features. Ten rounds of each of two types of genuine ammunition bearing the identical or similar head stamps as the homemade ammunition selected were also examined. Three more rounds of each type of homemade ammunition were test fired to obtain gunshot residue (GSR) samples. The designated sample names, ammunition type, and head stamps of the 9-mm Luger ammunition studied in this work are shown in Table 1.

Methods

Unfired ammunition was disassembled using an inertia bullet extractor to recover the bullet, gunpowder grains, and primed cartridge case. The morphology of the bullet and propellant powders obtained from each type of ammunition were examined and compared with other types of ammunition. The weight, diameter, and length of each bullet were measured, and their mean values and standard deviations were calculated. The length, outer mouth diameter, rim diameter, and mouth-wall thickness of each cartridge case were measured, and their mean values and standard deviations were calculated. A t-test was used to establish the significance of differences in all measured forensic features between the genuine ammunition and the homemade ammunition; a confidence level of 95% (p-value = 0.05) was chosen for the test.

The manufacturing marks on the head stamps of each type of ammunition and the tool marks on the inner surface of the homemade cartridge cases were carefully examined, and a comparison microscope was used to compare them with their genuine counterparts. The morphology of the gunpowder grains obtained from each type of ammunition was examined and compared with the other types of ammunition. The composition of the major organic ingredient of the gunpowder grains was identified using an FT-IR.

A small piece of each bullet jacket, bullet core, and cartridge case were separately mounted on different SEM sample stubs using doubled-sided carbon tape and were subjected to elemental analysis using SEM/EDS. The Boxer-type primer cups of unfired cartridge cases were deprimed, and primer mixtures were then recovered from the primer cups after removing the anvils. Primer mixtures were mounted on SEM sample stubs coated with carbon and subjected to elemental analysis using SEM/EDS. Test firings were conducted using one thoroughly cleaned Beretta Model 92 FS pistol. GSR samples were collected from the inside of spent cartridge cases and were then coated with carbon prior to SEM/EDS analysis.

TABLE 1—*Sample name, ammunition type, and head stamps of ammunition under study.*

Sample Name	Ammunition Type	Head Stamps
IA	Homemade	AP 03 9 MM LUGER
IW	Homemade	WIN 9 mm LUOER*
GA	Genuine	AP 03 9 MM LUGER
GW	Genuine	WIN 9 mm LUGER

*Note the spelling error in "LUOER."

Results and Discussion

According to the arrangement and content of the head stamps on the homemade ammunition, it is postulated that the IA ammunition was intended to imitate the 9-mm Luger ammunition manufactured by the Arms Corporation of the Philippines, and the IW ammunition is a deliberate imitation of this same ammunition from the Winchester Ammunition Company. Thus, genuine ammunition made by the Arms Corporation of the Philippines (designated as GA) and the Winchester Ammunition Company (designated as GW) was chosen as the control samples for the purpose of comparison. Figure 1 shows that the IA and GA ammunition have the same head stamps, "AP 03 9 MM LUGER." The analogous head stamps of IW and GW ammunition are shown in Fig. 2. The spelling error in the word "LUOER" on the head stamps of the IW ammunition suggests that it is not genuine.

FIG. 1—*The head stamps of IA (right) and GA ammunition (left).*

FIG. 2—*Head stamps of IW (right) and GW ammunition (left).*

FIG. 3—*The appearance of a GW bullet (left), an IW bullet (middle), and an IA bullet (right).*

Although the round-nosed full metal jacket bullets of the homemade ammunition show a strong resemblance to their genuine counterparts, morphological differences are observed between these two types of ammunition. Figure 3 shows that the homemade bullet has a groove that is crimped by the cartridge case mouth, whereas the genuine bullet has no grooves. A boat-tail configuration of the IW bullet (Fig. 3) is another significant feature of this homemade ammunition. In addition, the circumference of the base of the genuine bullet's lead core is enclosed by the metal jacket; however, the base of the homemade bullet's lead core is entirely exposed (Fig. 4).

Mean values and standard deviations of the weights and dimensions of the studied bullets are shown in Table 2. The *p*-values of the *t*-test of the mean values of all bullet pairs compared are shown in Table 3. We observed that the weights and dimensions of the homemade bullets are smaller than those of their genuine counterparts. According to the results of *t*-test using the confidence level of 95%, there are significant differences between the weights, diameters, and lengths of the homemade bullets and their genuine counterparts, with the exception of the weights of the IW bullets as compared to the GW bullets.

Cartridge cases of both the homemade and genuine ammunition have the rimless-type case base and a Boxer-type center-fire primer. Both silver-colored and brass-colored cartridge cases are observed in the IA and GA samples. In contrast, the GW samples only have brass-colored cartridge cases, and the IW samples only have dark-silver-colored cartridge cases. The detailed dimensions of the cartridge case length, outer mouth diameter, rim diameter, and mouth-wall thickness for all types of ammunition are shown in Table 4. The *p*-values of the *t*-test of the cartridge case dimensions for all ammunition pairs compared are shown in Table 5. Because the examined homemade ammunitions are designed to be fired through 9-mm Luger firearms, the outer mouth diameter and the length of the cartridge case should be in accordance with the genuine ammunition. As expected, there are no significant differences in case length between the genuine ammunition and their imitations. There are also no significant differences in the diameter of the case outer mouth between IA and GA ammunitions. The diameter of the case outer mouth in IW ammunition is slightly larger than the other types of ammunition, and there is a significant difference in the diameter of the case outer mouth between IW and GW ammunitions. Both types of homemade ammunition, namely, IA and IW, have larger rim diameters and mouth-wall thicknesses than the genuine GA and GW ammunitions. Significant differences in rim diameter and mouth-wall thickness between homemade and genuine ammunitions are observed in statistical tests. Because the homemade cartridge case is made of a solid brass rod with a hole drilled down the center, it requires a thicker wall to acquire the same strength as the genuine cartridge case. In contrast, an industrially manufactured cartridge case is made of a brass strip that is punched, cupped, drawn, and formed to shape and thus has a thinner case wall. Figure 5 shows the difference in appearance between the inner surfaces of a homemade cartridge case and a genuine cartridge case; the former has drilling marks, whereas the latter does not. The thicker case wall results in a small inner diameter of the case mouth, and thus, a bullet <9 mm in caliber can be used to fit the homemade case mouth. This also results in a smaller bullet

FIG. 4—*The bullet base of a GW bullet (left), an IW bullet (middle), and an IA bullet (right).*

TABLE 2—*Mean values and standard deviations for bullet weights and dimensions.*

Sample Name	Weight (g)	Diameter (mm)	Length (mm)
IA (n = 7)	7.23 ± 0.06	8.80 ± 0.02	14.33 ± 0.27
GA (n = 10)	8.09 ± 0.05	8.95 ± 0.01	15.21 ± 0.21
IW (n = 7)	7.39 ± 0.13	8.76 ± 0.04	14.24 ± 0.10
GW (n = 10)	7.47 ± 0.02	8.98 ± 0.02	15.05 ± 0.16

TABLE 3—*The* p-*values of the* t-*test for bullet weights and dimensions.*

Sample Pair	Weight	Diameter	Length
IA and GA	3.34×10^{-13}	7.40×10^{-6}	9.19×10^{-6}
IW and GW	0.20	7.29×10^{-9}	1.70×10^{-7}

TABLE 4—*Mean values and standard deviations of cartridge case dimensions.*

Sample Name	Length (mm)	Outer Mouth Diameter (mm)	Rim Diameter (mm)	Mouth-Wall Thickness (mm)
IA (n = 7)	19.05 ± 0.02	9.57 ± 0.03	9.99 ± 0.03	0.38 ± 0.03
GA (n = 10)	19.04 ± 0.06	9.56 ± 0.01	9.85 ± 0.02	0.23 ± 0.01
IW (n = 7)	19.08 ± 0.05	9.61 ± 0.03	9.91 ± 0.02	0.37 ± 0.01
GW (n = 10)	19.02 ± 0.07	9.50 ± 0.02	9.83 ± 0.02	0.26 ± 0.03

TABLE 5—*The* p-*values of the* t-*tests for cartridge case dimensions.*

Sample Pair	Length	Outer Mouth Diameter	Rim Diameter	Mouth-Wall Thickness
IA and GA	0.23	0.09	1.68×10^{-7}	8.64×10^{-5}
IW and GW	0.14	3.28×10^{-6}	1.20×10^{-5}	9.62×10^{-7}

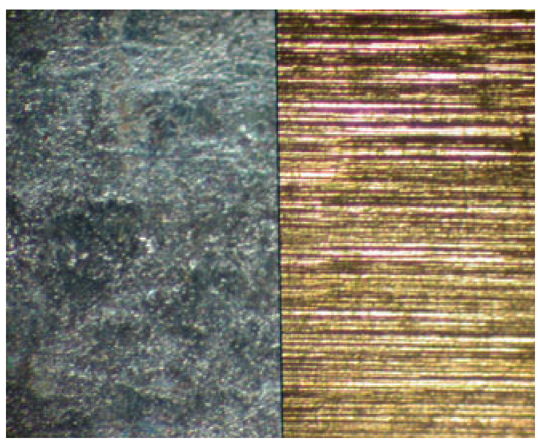

FIG. 5—*The inner surfaces of genuine (left) and homemade (right) cartridge cases observed under a comparison microscope.*

weight for the homemade ammunition as compared to its genuine counterpart.

After microscopic comparison of the tool marks on the head stamps of the IA ammunition, two different types of manufacturing marks were observed. Figure 6 shows the comparison of two cartridge cases with head stamps marked with the same type of tool marks. In contrast, Fig. 7 shows the comparison of two cartridge cases with different types of tool marks. These results indicate that at least two bunters are used to mark the head stamps on IA cartridge cases. Head stamp comparisons of GA and IA cartridge cases show that they are from different origins (Fig. 8). The head stamps of IW and GW cartridge cases can be easily differentiated because of the spelling error in the word "LUOER" marked on the IW cartridge cases. A comparison of the head stamps between different IW cartridge cases shows that they were stamped by the same bunter (Fig. 9).

Morphological characteristics play important roles in the identification of unfired gunpowder grains and their discharged residues (9). Our results show that only two rounds of IA ammunition have a mixture of two differently shaped gunpowder grains, namely, green disk flakes and black flattened balls (Fig. 10). Gunpowder grains from the rest of the IA ammunition and all of the GA ammunition appear as black flattened balls. The similarities of gunpowder grains between GA and IA ammunitions suggest that they could be propellants that originated from a common source and were distributed to various cartridge-loading manufacturers (10). Gunpowder grains from all IW ammunition are in the shape of black flattened balls. However, various shapes of gunpowder grains are observed in samples collected from different rounds of GW ammunition, including black flattened balls, blackish green disk flakes (Fig. 11), and blackish green flattened balls. The identical

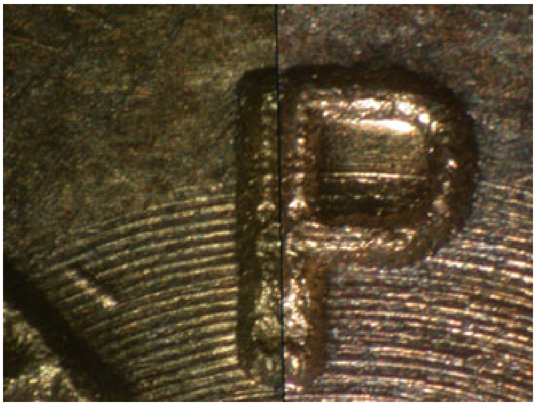

FIG. 6—*Microscopic comparison of the same type of tool marks on IA head stamps.*

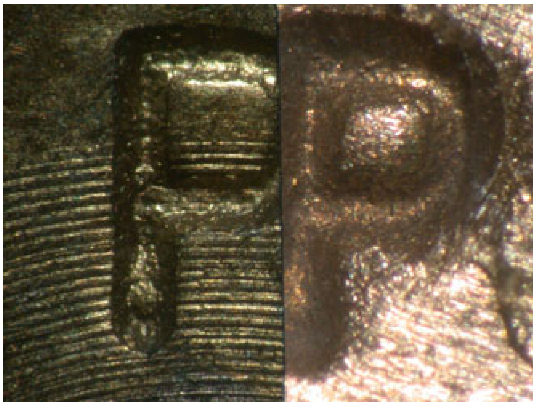

FIG. 7—*Microscopic comparison of two different types of tool marks on IA head stamps.*

FIG. 8—*Head stamp comparison of IA (left) and GA (right) cartridge cases.*

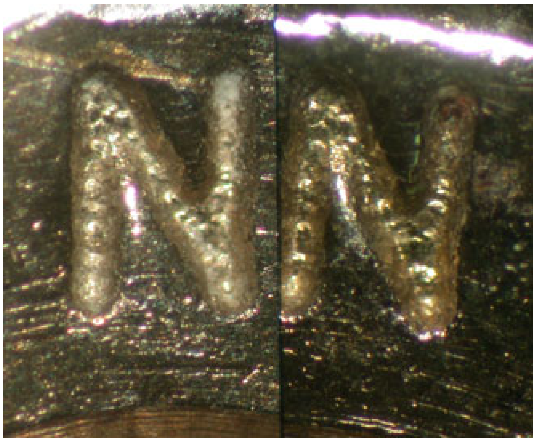

FIG. 9—*Comparison of head stamps on two different IW cartridge cases.*

FIG. 10—*A mixture of two differently shaped gunpowder grains observed in IA ammunition.*

FIG. 11—*The blackish-green disc shaped gunpowder observed in GW ammunition.*

head stamps provide evidence that all GW ammunitions were possibly made by the same manufacturer. However, the differences in the shapes of the gunpowder reveal that they are from different manufacturing lots. The results of FT-IR analysis show that propellants from all types of ammunition constitute smokeless gunpowder that contains nitrocellulose (NC) as its major ingredient. The IR spectra of standard NC and gunpowder collected from IA ammunition are shown in Fig. 12.

The elements detected in the major parts of the ammunition under study using SEM/EDS analysis are shown in Table 6. The results show that the cases of all brass-colored cartridges are made from a copper-zinc alloy. In addition to copper and zinc, nickel is detected in silver-colored genuine cartridge cases, and aluminum and nickel are detected in silver-colored homemade cartridge cases. Aluminum is a characteristic elemental component of silver-colored homemade cartridge cases; this fact can be used to differentiate them from the real ones. A typical EDS spectrum of an IA cartridge case is shown in Fig. 13. Further SEM/EDS analyses of the cross-sections of all cartridge case samples reveal that they are all composed of brass. For the silver-colored cartridge case, only a thin coating of Ni or Al-Ni is plated onto the external surface of the Cu-Zn case to give it a silver appearance.

The elemental composition of all bullet cores analyzed in this study is lead. The lead core of the homemade bullets is covered with a copper jacket. Pure copper is seldom used as a bullet jacket because it is softer than the copper-zinc alloy (11). Thus, homemade bullets can be easily differentiated from industrially manufactured bullets that have a copper-zinc alloy jacket.

All industrially manufactured ammunitions use modern noncorrosive primer mixtures that contain lead styphnate as an initiator, barium nitrate as an oxidizer, and antimony sulfide as the fuel. The elements barium, antimony, lead, and sulfur are detected in all of these primer mixtures. The detection of K and Cl in the primer mixtures of all homemade ammunition is an indication that obsolete corrosive primer mixtures containing potassium chlorate are used. In addition to the elements Si, P, Ca, S, Cl, and K, the primer mixtures in IW ammunition also contain Mg. Thus, the detection of Mg can be employed to distinguish IW ammunition from IA ammunition. The use of these types of homemade ammunition greatly complicates the interpretations of GSR analysis by forensic scientists because GSR originating from corrosive primer mixtures does not have the characteristic elements Pb, Sb, and Ba (12,13). Local forensic scientists should be very careful to avoid false negative conclusions of the GSR detection resulting from the use of homemade ammunition.

The results of the GSR analysis using SEM/EDS further show that the elemental profile of the GSR from IA ammunition contains Si, P, Ca, S, Cl, K, Cu, and Zn, and that of the GSR from IW ammunition contains Si, P, Ca, S, Cl, K, Mg, Cu, and Zn, where

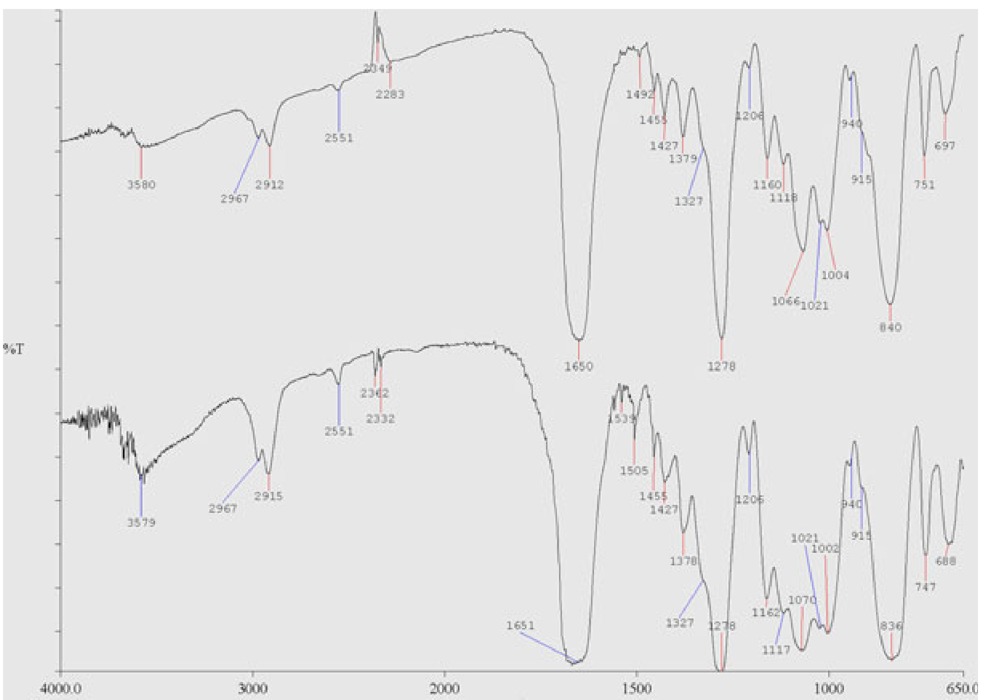

FIG. 12—*IR spectra of standard NC (bottom) and the powder of IA ammunition (top).*

TABLE 6—*Elements detected in the major parts of examined ammunition.*

Sample Name	Cartridge Case	Bullet Jacket	Bullet Core	Primer Mixtures
IA-B*	Cu, Zn	Cu	Pb	Si, P, Ca, S, Cl, K
IA-S†	Al, Cu, Zn, Ni	Cu	Pb	Si, P, Ca, S, Cl, K
GA-B*	Cu, Zn	Cu, Zn	Pb	Pb, Sb, Ba, S
GA-S†	Cu, Zn, Ni	Cu, Zn	Pb	Pb, Sb, Ba, S
IW-S†	Al, Cu, Zn, Ni	Cu	Pb	Si, P, Ca, S, Cl, K, Mg
GW-B*	Cu, Zn	Cu, Zn	Pb	Pb, Sb, Ba, S

*Ammunition with brass-colored cartridge case.
†Ammunition with silver-colored cartridge case.

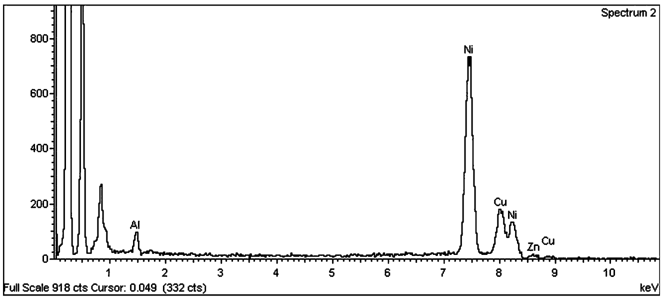

FIG. 13—*Typical EDS spectrum of an IA cartridge case.*

Mg is characteristic of IW ammunition and Cu and Zn are elemental sources used in the cartridge case. Both elemental profiles are not characteristic of GSR. In addition to the specific elements Pb, Sb, and Ba in the GSR, the permitted GSR elements defined by Wolten et al. (14) are Si, Ca, Al, Cu, Fe, S, P, Zn, Ni, K, and Cl. Because the GSR generated from IW ammunition contains Mg, it could be regarded as inconsistent with the GSR without knowledge of the elemental composition of its primer mixtures. Because the elemental composition of GSR is primer-type-dependent, the comparison of suspected GSR particles with the GSR of a spent cartridge case is critical for the meaningful interpretation of results.

Conclusions

Although homemade ammunition is indistinguishable from genuine ammunition for the first glimpse, there are a number of morphological, dimensional, and compositional differences between homemade and industrially manufactured ammunition. These features cannot only be used to distinguish homemade ammunition from genuine ones, but they can also be employed to trace the origin of illegal homemade ammunition. Among these features, tool marks on the head stamps left by the bunter are the most valuable in the identification of the common origins of ammunition captured from different criminal incidents.

Head stamps are usually used to identify the manufacturer, caliber, and manufacturing year of ammunition. However, homemade ammunition with forged head stamps can be misleading to an inexperienced firearms examiner. To avoid mistakes, systematic observations of the morphological characteristics and measurements of the dimensional features of the examined ammunition should be performed before the identification of head stamps. Elemental analysis of major parts of the ammunition can be used in advanced procedures to identify the cartridge in question.

Because homemade ammunition is frequently encountered in shooting incidents in Taiwan and because the elemental composition of the GSR is mainly determined by the composition of the primer mixture, a comparison of the suspected GSR sample with GSR collected from a spent cartridge case is even more important than ascertaining the uniqueness of the GSR elemental profile to reach a correct interpretation of the GSR detection results.

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