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Technical Note

# A study into the distribution of gunshot residue particles in the random population

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ABSTRACT

When considering the impact and value of gunshot residues (GSR) as forensic trace evidence, the likelihood of a suspect producing a positive GSR analysis result without having direct exposure to a firearm is a major consideration. Therefore, the random prevalence of GSR and 'GSR-like' residues in the wider population is a highly pertinent question when considering the probative value of such evidence. The random prevalence of GSR in two Australian jurisdictions – Victoria and South Australia – was assessed through the collection and analysis of GSR samples obtained from randomly selected members of the public. Volunteers were asked to declare any firearms use, hobbies or potential firearms exposure before allowing their hands to be sampled using aluminium GSR sample stubs coated in adhesive tape. A total of 289 samples, 120 from Victoria and 169 from South Australia were collected and analysed using scanning electron microscopy coupled with energy dispersive X-ray microanalysis (SEM-EDS). Across all samples, three 'characteristic' three-component Pb/Ba/Sb particles were detected from a single subject in South Australia, corresponding to an overall prevalence of 0.3%. Two-component 'consistent' particles were more prevalent, with Pb/Sb particles being the most frequently occurring, in 8% of samples, and in South Australia only. A number of samples, approximately 7%, showed populations of single element particles of Pb, Ba and Sb, which has the potential to generate a false positive for GSR if using a bulk analysis technique such as NAA or AAS. The prevalence of GSR or 'GSR like' particles in this study matches closely with similar surveys conducted in other jurisdictions. Such surveys are a useful foundation for the creation of a probabilistic method for the assessment of GSR evidence.



## 1. Introduction

When considering the impact and value of gunshot residues (GSR) as forensic trace evidence, the likelihood of a suspect producing a positive GSR analysis result without having direct exposure to a firearm is a major consideration. Therefore, the random prevalence of GSR and 'GSR-like' residues in the wider population is a highly pertinent question when considering the probative value of such evidence. This raises the possibility of applying a probabilistic interpretation to GSR results. Biedermann et al. [1,2] have proposed a Bayesian approach to GSR evidence. They state in order to evaluate competing hypotheses (usually that a person has discharged a firearm and that the person has not) two important factors must be addressed – (i) the number of GSR particles expected and (ii) the probability of random occurrence of GSR. The first factor is difficult to address, as it depends on a number of variables, including firearm and ammunition. However, tests with the questioned weapon and ammunition can be undertaken for each case situation. The second question can be addressed by undertaking random GSR sampling in the general population.

Previous population studies, conducted in Europe (Italy [3] and Poland [4]), are most applicable to the countries in which they were conducted. Differences in firearms laws and availability in different countries may be expected to result in differences in the background prevalence of GSR in the wider population. This may

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be considered of particular relevance in Australia, where a comparatively greater proportion of firearms encountered in casework are of the 0.22 rimfire variety or 12 gauge shotguns. GSR originating from ammunitions of this type may present significant challenges in the identification of detected particles: many 0.22 calibre rimfire primers produce Pb/Ba residues and many 12 gauge ammunitions produce predominantly Ba/Al particles with relatively few three-component particles being detected. With that in mind, a survey specific to the Australian environment is warranted in order to accurately assess the prevalence of GSR and 'GSR-like' particles at random in Australia.

## 2. Materials and methods

### 2.1. Research reported in this paper

This survey was an initiative carried out on behalf of the Criminalistics Specialist Advisory Group (SAG) of the Senior Managers of Australian and New Zealand Forensic Laboratories (SMANZFL).

Sample collection and analysis was carried out independently in two states, Victoria and South Australia, by accredited forensic science laboratories – the Victoria Police Forensic Services Centre (VPFSC) and Forensic Science SA (FSSA).

The initial results from 41 of the 120 subjects sampled in Victoria were reported by Condon in Honours work conducted at Deakin University.

### 2.2. Subject selection

Samples were collected from volunteer members of the public at two different geographical locations in Victoria, a metropolitan shopping centre (Preston) and a regional market (Geelong), and nine metropolitan locations in Adelaide. Appropriate ethics and privacy approvals were obtained. Questionnaires were used to establish, amongst other information, whether the volunteer had any association with firearms. Minor differences existed between the questionnaires used in the two states, but the same relevant information was collected. Both questionnaires requested the age group and hand preference of volunteers, as well as asking them to disclose if they had handled or fired a firearm in the last 5 h (Victoria) or 4 h (South Australia), if they had any hobbies related to firearms, and when they had last washed their hands. Both questionnaires asked if volunteers worked in professions that may result in GSR or 'GSR-like' particle exposure (i.e., police, military, pyrotechnic technicians, building, automotive or agricultural industries). However the Victorian questionnaire required volunteers to nominate if they were a member of a list of specified professions, while the South Australian questionnaire asked volunteers to declare their profession.

The Victorian survey further asked if the volunteer worked with or regularly handled metals that may be present in GSR (i.e., Pb, Ba, Sb, Zn, Cu, Si, and Al) or if members of the volunteer's household worked in high exposure risk industries, or had firearms hobbies. The South Australian survey asked volunteers to nominate what they had been doing with their hands for the last 4 h. Anonymity of participants was ensured. Samples were collected from a total of 289 subjects – 120 in Victoria and 169 in South Australia.

### 2.3. Sample collection

Sample collection was performed using each laboratory's documented GSR procedures, which ensured that the survey replicated the way in which case samples would be collected. Samples were collected on standard 12.5 mm SEM pin stubs held in closed plastic vials. The stubs used in Victoria were covered with transparent double sided adhesive tape and those used in South Australia had double sided carbon adhesive tape.

There were minor variations in the sampling procedure used in the two states. In Victoria, a separate stub was used for each hand and more extensive dabbing conducted over the top of the thumb, forefinger and web, followed by the palm and underneath the thumb and forefingers. In South Australia, one stub was used to sample both hands, starting with the volunteer's nominated favoured hand. After removing the paper backing to expose the adhesive surface, the stub was dabbed around the forefinger, followed by the webbing and then the thumb. Following sampling the stubs were returned to the vials.

Samples were carbon coated prior to analysis by SEM-EDS using automated particle searching software.

#### 2.3.1. Instrumentation and analysis

The Victorian instrument was a CamScan Apollo SEM with Genesis EDS system. The South Australian instrument was a Zeiss Evo 50 SEM with Oxford EDS system.

Each laboratory used different set up and monitoring procedures, but all analyses were performed in accordance with each institution's validated, documented and accredited procedures for GSR analysis, ensuring that samples were exposed to the same conditions that case-samples would experience. This included measures to prevent laboratory contamination.

*VPFSC*: The backscatter signal set-up standard was gold, niobium, germanium, silicon, carbon (Au, Nb, Ge, Si, C) and Faraday cup (eastern analytical). The positive control was prepared in house by sampling the back of a hand immediately after the discharge of a Smith and Wesson 0.38 revolver.

*FSSA*: A Gold/Cobalt/Rhodium/Carbon (Au/Co/Rh/C) standard (Micro-Analysis Consultants Ltd, United Kingdom) was used to set up brightness and contrast settings to allow for the automated particle search system to detect particles based on the signal generated from the backscatter detector. A SPS-Synthetic Particle Specimen (Plano GmbH, SPS-A521-2(27C)) standard was used as a positive control at the start and end of every automated run. It is a silicon chip with 43 precipitated Pb/Sb/Ba particles, ranging in size from 1 μm to 5 μm. For a valid analysis, the automated particle search system had to identify 40 out of 43 particles at both the start and end of the run.

At the end of each automated run, particles classified as GSR were manually reviewed by an analyst in order to assess their morphology and composition before being excluded or confirmed as GSR. Although data acquisition conditions were not identical across the two laboratories, both instruments were capable of reliably detecting gunshot residue particles down to a size of 0.5 μm and, therefore, their performance can be considered to be equivalent for all practical purposes in regards to this survey.

## 3. Results and discussion

The following particle classification, based upon the ASTM standards [5] and protocols of the forensic laboratories that carried out the analysis, was used:

- The three element combination (Pb/Sb/Ba) was considered characteristic of a GSR origin.
- Two element combinations (e.g., Pb/Sb, Pb/Ba, Sb/Ba) were considered consistent with a GSR origin.
- Au, Fe, La/Ce, etc. were considered common environmental particles.

Data from subject information sheets revealed that six of the subjects in Victoria (5.0% of Victorian subjects) declared personal firearms hobbies – including hunting, sports shooting, or