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THE RELATION BETWEEN GUNSHOT RESIDUE PARTICLE SIZE AND BOLTZMANN DISTRIBUTION

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Gunshot residue (GSR) is also commonly known as cartridge discharge residue (CDR) or gunfire residue (GFR) or firearm discharge residue (FDR). GSR is an important form of trace evidence that would pave the way for investigation. GSR is found in solid, liquid, or gaseous state under high exothermic reactions due to high temperature and pressure and is any mixture of burnt and unburnt materials that originate from a firing gun and get deposited on the hands, or clothes of the person who discharges the firearm. The residue can include substances from primer, projectile, cartridge cases, etc. Gunshot residue can travel over 3-5 feet (0.9-1.5m).

GSR analysis is majorly done to determine whether a firearm has been used. Determination of the structural distribution of GSR would help in its analysis. Primer particles contain lead (Pb), barium (Ba), and antimony (Sb) and hence they are analyzed by using sodium rhodizonate test scanning electron microscopy with energy dispersive x-ray detection. According to various studies, it is found that GSR consists of spherical particles as a result of random distribution. But under this study, it describes GSR

particles based on a specific distribution function. The Boltzmann distribution function is the most basic and probable principle, the dimensional size distribution of GSR particles was analyzed according to this principle.

METHOD USED AND ANALYSIS

Sarsilmaz Kilinc (9mm)2000 mega-brand semiautomatic pistol was used for test firing, with full metal jacket cartridges that were produced by a 9 mm x 19 mm Parabellum-type MKE, Geco, S&B, WIN, and LIBRA. The samples were collected from the shooter's right hand (especially from regions of the thumb and index finger) with the help of double-sided adhesive tape glued to aluminum stubs. Before each shot, the weapon barrel was cleaned by mechanical cleaning or even in an ultrasonic bath of ethanol and deionized water before being dried with dry nitrogen gas. The collected GSRs were analyzed using the specified techniques.

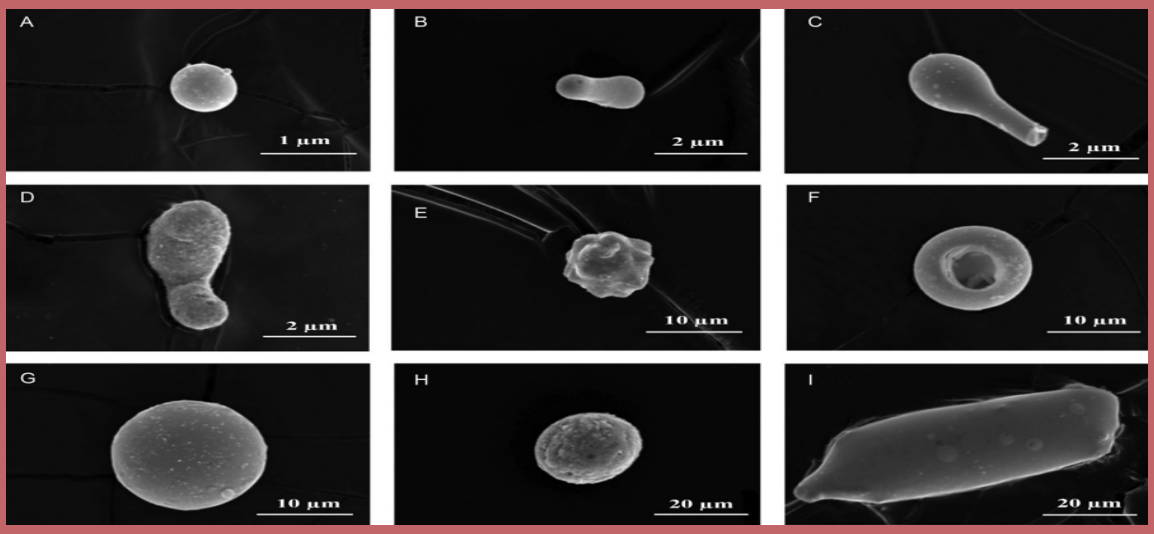

Figure 1. GSR particles of different sizes formed by fragmentation splitting and external factors.
https://www.tandfonline.com/doi/full/10.1080/20961790.2020.1713433

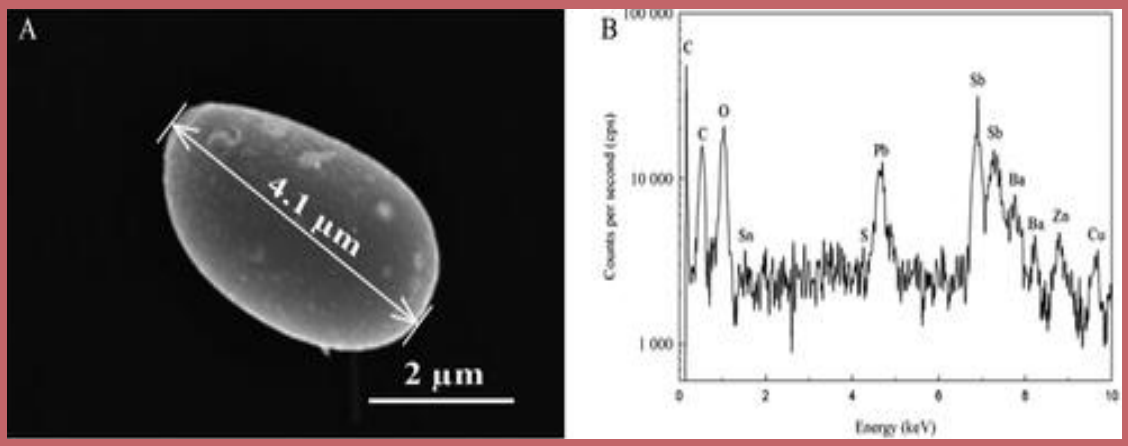

Figure 2 .GSR particle size measurement(A), EDS spectrum(B). https://www.tandfonline.com/doi/full/10.1080/20961790.2020.1713433

DIMENSIONAL ANALYSIS

The dimensional classes of GSR are obtained using the sizes (r_1) of the primary particles of the GSR and the total number of particles (m_1). The density of the primary class can be determined from r_k = r_1 based on basis of Enskog–Boltzmann's theory, the dimensional distribution ratio of the GSR particles depends on splitting–merging and external factors.

According to the study the size distribution of the dimensional classes was found to be similar to that of the inverse square method (Boltzmann distribution).

The results are based on:

- merging effect of adhesion forces.
- the effect of unbalanced forces split due to excess surface energy
- fragmentation because of external.

BOLTZMANN DISTRIBUTION

The basic equation for the number of molecules with variable velocities and energies is found in the Boltzmann

distribution. Gas molecules move at various velocities and in various directions for the model as it is based on kinetic molecular theory. The distance of each molecule to its starting point is proportional to the magnitude of the molecular velocity, and hence the molecule behaves isotropically.

If molecules are small then their velocity increases rapidly, therefore, the velocities of molecules at the same temperature are inversely proportional to the square root of molecular masses. The results experimentally prove Graham's law.

MATLAB COMPUTER PROGRAM

The result obtained through the experiment was transformed into data that are converted as model curves. The data in the intervals showed behavior that conformed to the inverse square method (Boltzmann distribution).

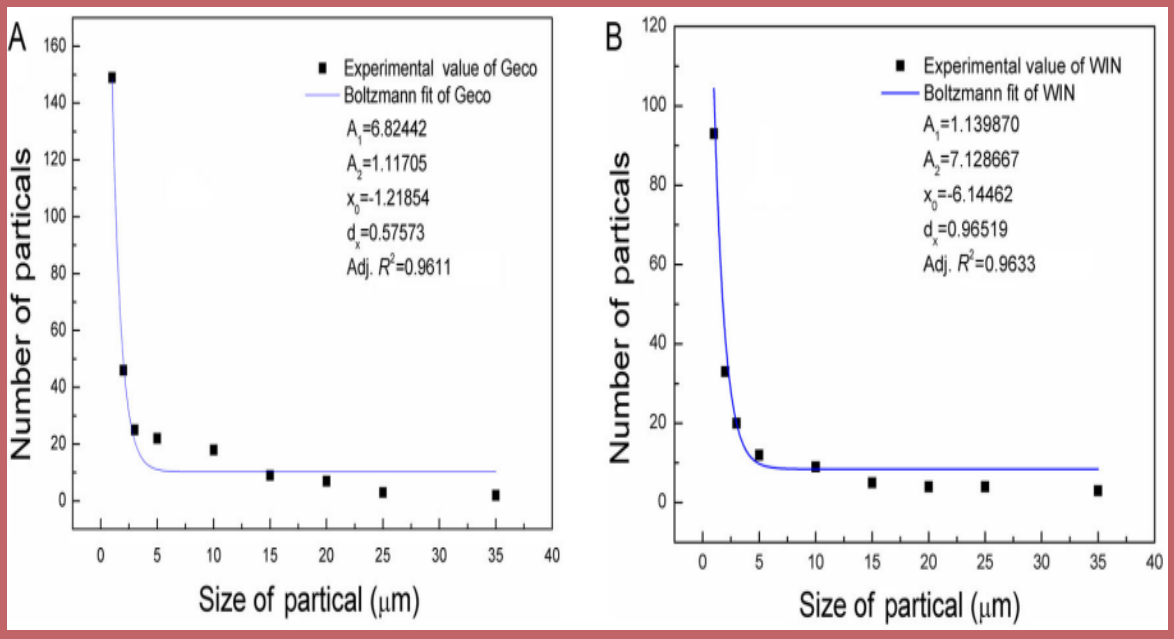

Figure 3. Fit curve of variation of GSR particle.
https://www.tandfonline.com/doi/full/10.1080/20961790.2020.1713433

CONCLUSION

This was an experimental study that gave a briefing about the quantitative analysis of particle size distribution properties of GSR. A GSR model was created strictly based on Boltzmann distribution. The data obtained through analysis in a simplified system were made into different groups. The particle size distribution was found to be consistent according to Boltzmann kinetic equation. The data created were analyzed using the MATLAB program wherein the results gave an overall outline for all GSR particles. If further improvements are made to this study, then that would help us to compare different brands and scales of ammunition.

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