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The Effects of Water-Soaking on Firing Distance Estimations

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ABSTRACT: The effects of water-soaking on firing distance estimations, employing quantitative determinations of gunpowder and metals around the bullet's entrance hole, were studied. The main finding was that, since the precision of the quantitative determination is poor, the existing statistical spread cancels out a potential effect of the target soaking. None the less, the prevailing factor is the firing distance, where increments of about 25 cm are clearly distinguishable, in both dry and water-soaked targets.

KEYWORDS: criminalistics, ballistics, water-soaked material

An accepted method used for the estimation of firing distances is measuring quantities of various materials which strike the victim's apparel along with the bullet [*1,2*]. In this method, one may measure either one of two major components: concentrations of metals, especially copper and lead, around the entrance hole, or the number of incompletely burned gunpowder particles. In the latter process, one uses a color reaction for the identification of nitrite ions [*3*]. In the former, the concentrations of copper and lead are determined within two rings around the hole [*4*]:

1. An internal ring (usually 16 mm in diameter) which contains the "ring of dirt." This ring is caused by the friction of the bullet during its penetration of the target and is characterized by relatively high concentrations of metals originating from the bullet [*5*]. These concentrations are not dependent on the firing distance;[2] however, their existence enables the identification of the hole as being a bullet entrance hole.
2. An external ring (usually 25 mm in diameter) where one measures the concentrations of the metals originating from the "cloud" of particles accompanying the bullet. These concentrations are the actual parameter used for the firing distance estimation. By comparing the concentrations around the entrance hole with those received in test-firings using the same weapon and type of ammunition, one can arrive at a firing distance estimation. The higher the metal concentration the shorter the firing distance.

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An important question arises in this kind of test: to what extent does soaking of the target influence the results of the measurements in question? This soaking can originate either from heavy bleeding from the wound, or in occasional cases where the target is water-soaked. An example of the last type of soaking can be a case where a body is found in a pool or pond, or has been exposed to inclement weather.

One might expect soaking to influence both metals and powder particle quantities by:

1. Causing a substantial decrease in metal concentrations within the internal ring, possibly by means of diffusion. Such a decrease could mislead and cause the examiner to identify the entrance hole as being an exit hole.

2. Changing the concentration within the external ring in two possible directions: (a) Decrease in the metal concentration as a result of diffusion in the outside direction. This would be wrongly interpreted as resulting from a longer range firing distance. (b) Increase of that concentration as a result of diffusion from the higher concentration in the internal ring. This would be wrongly interpreted as coming from a shorter range firing distance.

Similar considerations are relevant in assessing the firing distance from the number of powder particles.

The question of the effect of soaking is occasionally raised in courtrooms and, as far as we know, has not been comprehensively answered in the forensic science literature. However, in a paper published in the *AFTE Journal* by Allen [*6*], there were preliminary results of experiments regarding blood-soaking of the targets. In these experiments, test shots were fired at cloth targets from a distance of 6 in. (15 cm) and were subsequently soaked in blood for varying periods of time. After the soaked targets had been air-dried, they underwent microscopic examination for partially burned gunpowder particles and were then processed using the Greiss method. Allen's main conclusion was that heavy blood-soaking could change the density and diameter of gunpowder residues developed on clothing.

In the present paper, similar research was conducted using water as a soaking media. Emphasis was placed on the reproducibility, or precision, of the measurements. In light of our results, Allen's conclusion should be regarded with some care.

Experimental Procedure

1. A .22″ Berreta semi-automatic pistol using WW22LR ammunition was discharged at a woven cotton targets, 20 by 20 cm in dimension.

2. A Perkin Elmer Model 403 atomic absorption spectrophotometer was used. Circles of 8- and 12-mm radius were cut out around the bullet entrance hole and leached for 2 h with 2 mL of a 1:3 (v/v) nitric acid solution, using analytical reagent grade nitric acid. Background specimens, obtained by cutting an 8-mm radius circle from an area of target cloth where a bullet had not penetrated, were run simultaneously. The circles were then removed from the solution, and the residue was analyzed.

3. Gunpowder particle quantities were determined in both internal and external rings, 4.5 and 14.5 cm in diameter, respectively. The determination was performed by using a modified Greiss method. The exhibit containing a bullet entrance hole is sprayed with 8% alcoholic KOH and placed in a drying oven at 110 to 120°C for 15 min. Photographic paper which has been stripped of its silver salts is sensitized with Greiss reagent for 5 to 10 min by placing the paper in a plastic tray and adding two parts of the sulfanilic solution to one part of the naphtylamine solution. The exhibit is placed on a clean white cloth with the bullet entrance hole facing up. The moist, sensitized photographic paper is placed with the emulsion side down on to the exhibit. A clean white cloth is placed above the photographic paper and the "sandwich" arrangement is ironed at moderate heat for approximately 5 min. The photographic paper is then removed and bright red-orange spots develop where nitrite ions were present. These spots were then counted.

Details concerning these methods are discussed elsewhere [7,8].

4. Test-firing was carried out at distances of 25, 50, and 100 cm in an outdoor range. The wind factor was negligible.

5. Soaking conditions: the targets were immersed in trays filled with deionized water, for 1, 24, and 48 h.

6. Each determination was based upon the mean result of six measurements of similar conditions, thus allowing a significance level of 95% for a three standard deviations range from the mean.

Results and Discussion

Apriori, several factors could affect the results of firing distance determinations on soaked targets.

1. The soaking media: water, blood, or any other liquid. Density, viscosity, and acidity may all have a possible effect.

2. The manner of soaking: immersion in still or flowing water, with or without shaking, and so forth.

3. The target material: woven or knitted textiles, synthetic, natural, and so forth.

4. Ammunition type: the difference between lead and copper and between these metals and powder particles (the difference between metals and organic matter) can result in various reactions with the soaking material.

However, before all these parameters are examined, one should consider a preliminary question concerning the precision of the method. The initial results obtained showed that this question becomes the most important one. Therefore, it sufficed to carry out experiments involving only part of the above mentioned parameters to draw the following conclusions.

Precision Testing

In Tables 1 and 2, results of the mean (x) and the standard deviation (sd) values of lead concentrations determined in the internal and external rings, respectively, are shown.

In Tables 3 and 4 results of the average (x) and the standard deviation (sd) values of the number of powder particles, in the internal and the external rings, respectively, are shown.

It is quite clear that the reproducibility of the results is very poor. The relative standard deviation (sd/x) values are 10 to 30% for metal determination results and 10 to 60% for gunpowder particles. These values correspond to both dry and water-soaked targets.

TABLE 1—*Concentration of lead, internal ring in microgram/square centimetres.*

Soaking Time, h	Firing Distance, cm					
	25		50		100	
	x	sd	x	sd	x	sd
0	52.6	11.6	29.6	4.6	27.5	13.8
1	53.2	5.2	29.1	2.6	27.3	15.6
24	42.2	4.9	29.2	5.2	26.7	10.4
48	58.9	10.7	27.1	3.3	28.0	26.0

TABLE 2—*Concentration of lead, external ring in microgram/square centimetres.*

Soaking Time, h	Firing Distance, cm 25 x	25 sd	50 x	50 sd	100 x	100 sd
0	18.4	4.7	3.0	0.7	0.0	0.0
1	21.1	4.1	1.7	0.6	0.3	0.3
24	18.0	4.6	3.1	0.9	0.8	0.4
48	19.3	6.8	2.8	0.9	0.5	0.4

TABLE 3—*Number of powder particles, internal ring.*

Soaking Time, h	Firing Distance, cm 25 x	25 sd	50 x	50 sd	100 x	100 sd
0	100	9	44	36	0	0
1	133	25	18	10	0	0
24	79	10	12	4	2	2
48	83	13	10	5	1	2

TABLE 4—*Number of powder particles, external ring.*

Soaking Time, h	Firing Distance, cm 25 x	25 sd	50 x	50 sd	100 x	100 sd
0	60	32	117	60	2	0
1	50	30	55	14	0	0
24	75	25	45	13	7	6
48	90	34	34	8	5	4

A plausible explanation regarding the precision of the metal concentration test would be the possibility that a small fragment introduced a substantial change in the metal concentration results. (This phenomenon is to be further explored, using the scanning electron microscope, in the next stage of the research.) Other possible factors contributing to the large spread of the results can be: variations in powder quantity, efficiency of the combustion process, the shape and mass of the bullet, and so forth. Varying shooting conditions, such as wind velocity, should also be taken into consideration. All these factors are valid when we use a single type of ammunition, and even more so when one must use different types of ammunitions and weapons for test comparisons.

The poorer reproducibility of powder particles can be attributed to the problem of losing particles from the target. This happens more readily with powder particles which are bigger and lighter than with metal particles. Another problem one faces when assessing the number of powder particles is the diffusion effect following the color development. This diffusion results in indistinct boundaries and difficulties in discriminating between adjacent particles. This last problem will, it is hoped, be solved by using the improved reagents for the color test reported elsewhere [9].

The importance of the question of precision cannot be overemphasized because in real cases, only one or two bullet holes are available, and conclusions must be drawn from test shootings based upon the result of a few (one or two) measurements.

In light of the above, the important point is that in spite of the wide spread of the results, we can still clearly discriminate between different shooting distances by means of the quantitative determinations. To demonstrate this finding, the data in Tables 2 to 4 were reorganized in Table 5, which presents the strong dependence of the measured quantities on the firing distance. The data in Table 1, metal concentration in the internal ring, is not included in Table 5, since these concentrations, generally, are not dependent on that distance. This last fact is reconfirmed in Table 1.

It is clear from Table 5 that even if a range of three standard deviations from the mean is taken, a discrimination between firing distances of 25, 50, and 100 cm is possible at a confidence of 95%. According to our experience, these three distances are sufficient, since the extension of the shooting hand may cover the distances in between.

Figures 1 and 2 present the influence of the firing distance on both metal and gunpowder particles concentrations, respectively. Results of dry and soaked targets are included.

Influence of Soaking

Figures 3 and 4 show the lead concentrations in the internal and external rings, respectively, as a function of soaking time.

The general impression received from these figures is that the soaking of the target does not have a substantial effect on the results. Even the slight differences after 1 h of soaking remain within the statistical spread.

Figure 5 shows the number of gunpowder particles as a function of soaking time. In some cases there is, indeed, a trend of decline in the number of particles after 1 h of soaking; however, in another case there is an increase, and in still another case, the number of particles increases at a longer soaking time. Remembering our self-required significance level of 95%, it is quite obvious that one cannot realize any definite regularity in the results.

TABLE 5—*Lead concentration and number of powder particles as a function of firing distance.*

Firing Distance, cm	Soaking Time, h	Lead Concentration External Ring, $\mu g/cm^2$		Number of Powder Particles	
		x	sd	x	sd
	0	18.4	4.7	238	70
25	1	21.1	4.1	245	35
	24	18.0	4.6	190	39
	48	19.3	6.8	207	33
	0	3.0	0.7	92	47
50	1	1.7	0.6	43	9
	24	3.1	0.9	60	10
	48	2.8	0.9	51	12
	0	0.0	0.0	5	3
100	1	0.0	0.0	0	0
	24	0.8	0.4	4	2
	48	0.5	0.4	2	2

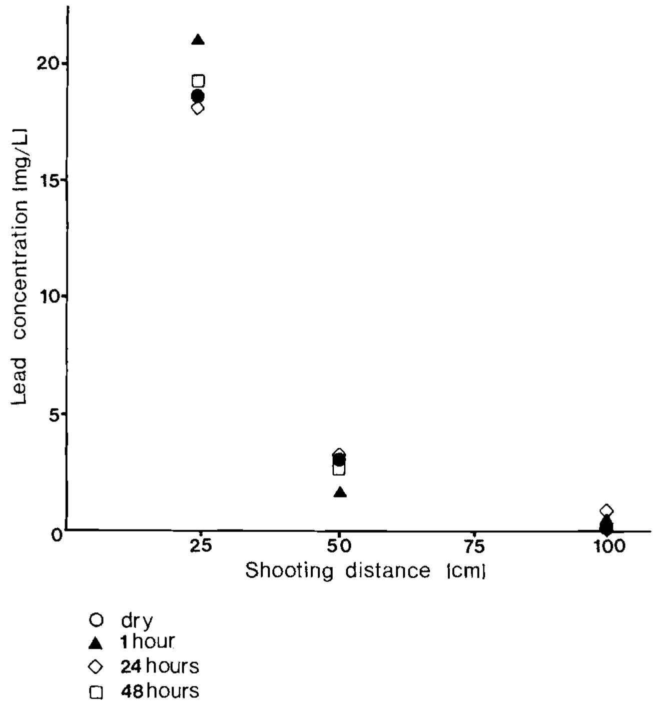

FIG. 1—*Lead concentration as a function of shooting distance at various soaking times, outer ring.*

One of the questions raised at the outset was whether or not soaking will have a noticeable influence on gunpowder particles. Because of their size and composition, there is a possibility that the liquid will cause floating of the particles resulting in their redistribution, thus leading to a false conclusion. Such a tendency can be seen in the results of 25-cm distance (Fig. 5), where soaking time between 1 and 24 h causes a decrease in the particle number within the external ring, while a similar increase in the internal ring occurs. The total number of particles remains approximately the same. However, at a 50-cm firing distance, the decrease appears in both the internal and external rings, and in 100 cm, no significant change can be detected at all.

Interpretation of the Results

As we have shown, the ambiguity of the results of the water-soaking of a target is due to the inherent statistical spread of the estimation method. While the "signal to noise ratio" is satisfactory enough for differentiating (?) between certain distances, this ratio does not enable one to detect a "soaking effect." While using this method of firing distance, estimation can be justified by these results, disregarding the possibility of water-soaking of the targets.

Conclusions

The precision of the "chemical" method for firing distance estimation on clothing was examined. For the type of weapon and ammunition tested (WW22LR), the precision was found to be quite poor. Although the method is clearly adequate for distance estimation, it was found that it is not sensitive enough to detect the effect of water-soaking on targets.

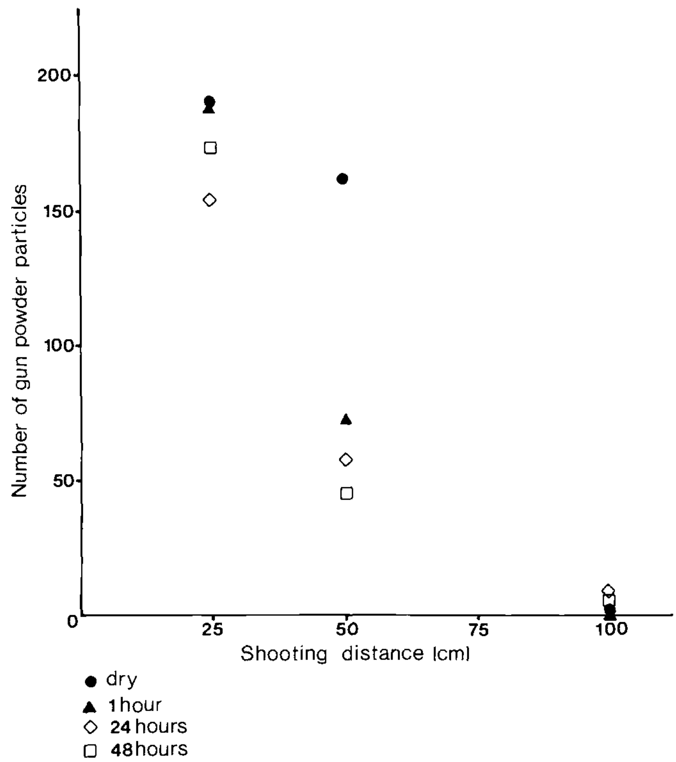

FIG. 2—*Number of gunpowder particles as a function of shooting distance at various soaking times.*

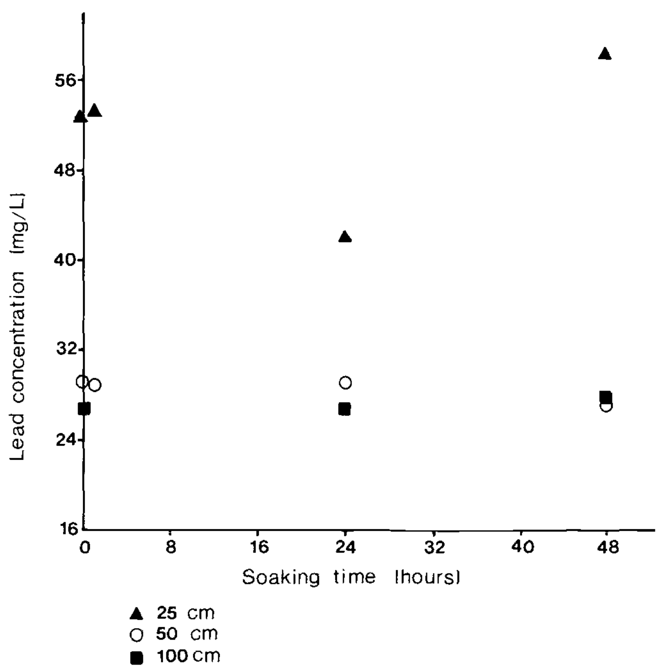

FIG. 3—*Lead concentration as a function of soaking time at various shooting distances, inner ring.*

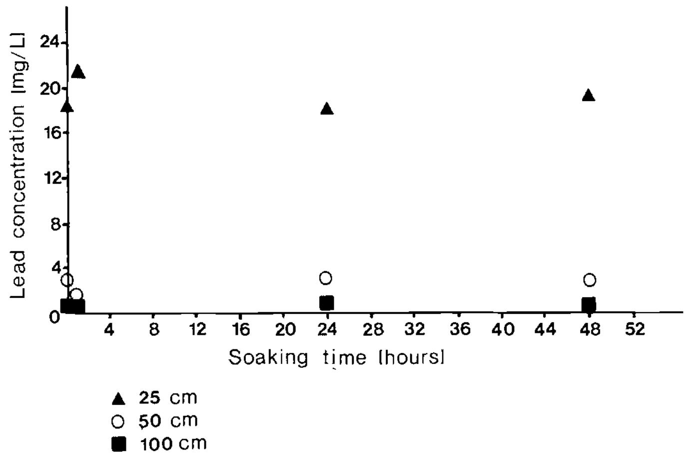

FIG. 4—*Lead concentration as a function of soaking time at various shooting distances, outer ring.*

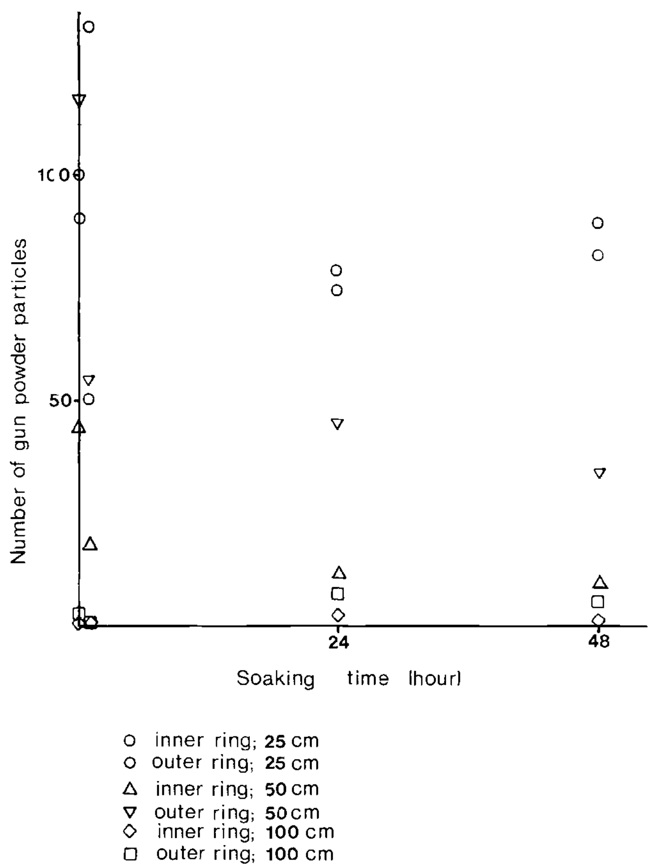

FIG. 5—*Number of gunpowder particles as a function of soaking time.*

Variables such as the effect of ammunition, weapon, target material, soaking liquid, and the kind of the soaking process have yet to be studied.

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