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How to Get Away with Murder: The Effectiveness of Blood Detectors on Surfaces Cleaned of Blood

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Abstract

The purpose of this experiment was to test blood detectors against household cleaners. Similar experiments have been run before, but not on the selected surfaces. It is important to understand what one is looking for at a crime scene, and what a cleaned surface may look like. Four surfaces were chosen for this experiment: ceramic tile as a control, concrete, laminated wood flooring, and drywall. For each surface, 0.5mL of pig's blood was allowed to dry before being cleaned off with either Clorox bleach, Dawn soap and hot water, a Mr. Clean Magic Eraser, or Mrs. Meyer's Multi-Purpose Concentrate. Bluestar and luminol were then applied to the surface. Results showed that concrete and drywall stained and retained blood, while ceramic tile and laminated wood were easier to clean off. Bleach and Mrs. Meyer's are the best cleaners to cover bloodstains and thus a capable of covering up a crime.

Introduction

Crime is not a new concept. Christians would argue that the first violent crime was between the brothers Cain and Abel, the sons of Adam and Eve. Cain was jealous of Abel, and so he murdered Abel. Forensic science has come a long way since Biblical times.

When a crime scene investigator (CSI) is called to a crime scene, once the scene's been secured, they are in charge of collecting and documenting forensic evidence. One part of such collection is testing for bloodstains. If there is a suspicious stain, CSI's can test the stain with luminol, Bluestar, or another blood detector to see if the stain is, in fact, mammalian blood. For violent crime scenes that have been cleaned before investigators arrive, it can be harder to test for possible blood stains.

Luminol, or 3-aminophthalhydrazide, was first synthesized in 1902 by Aloys Schmitz (Grispino, 1990). Schmitz noted that, in acidic solutions, luminol fluoresced bright blue. It wasn't until 1927, though, that W. Lommel tested luminol on an oxidized alkaline solution (Grispino, 1990). Lommel didn't publish, but in 1928 a coworker confirmed Lommel's original findings. The coworker, Herbert Albrecht, through further experimentation with luminol, found that the chemical reacted with blood and potato juice when mixed with hydrogen peroxide. It wasn't until 1934, though, that luminol earned its name because of the light it emitted (Huntress et al, 1934). Luminol was introduced to the forensic field in 1937 by Walter Specht, who sprayed blood on an outside sitting area and allowed the blood to remain for two weeks (Grispino, 1990). He then sprayed luminol on the area and photographed the evidence, which glowed for 10 to 15 minutes, even in the water and sewage (Grispino, 1990). Specht noted that the older the bloodstain, the better the reaction with luminol (Grispino, 1990). L. Lytle and D. Hedgecock recommended using luminol as a field test because it was nondestructive to the area around the

bloodstain, and wouldn't affect ABO or identification tests, or allow for electrophoretic analysis (Lytle et al, 1978).

Bluestar is a brand-specific blood detector that was created as a competitor to luminol. Originally meant for hunters, it could be used to track and locate a wounded animal (Dilbeck, 2006). The pH of the original formula, though, was not meant for forensics, so it was unsuitable for DNA processing as the DNA would denature when exposed (Dilbeck, 2006). In 2005, a company called ROC Import Group reworked the Bluestar formula to make the pH a little bit more acidic so it wouldn't destroy the DNA (Dilbeck, 2006). With the new pH, Bluestar was released for forensic work and would be suitable for short tandem repeats (STR) and polymerase chain reaction (PCR) processes (Dilbeck, 2006).

Hemascein is another name-brand blood detector that was developed around 2012 (Lowis et al, 2012). As a relatively newer blood detector, it is considered generally less reliable than luminol and Bluestar, which have been tested over the years. Hemascein does not have the years of practical use because of its newness, and so is considered less reliable. Hemascein has several other limitations when compared to luminol and Bluestar (Seashols et al, 2013). False-positive reactions were noted when Hemascein was exposed to red kidney beans, red onions, tomato and tomato sauces, floor and carpet cleaner, and bleach, although it was also more sensitive than luminol and Bluestar on other surfaces like fabrics and linoleum (Seashols et al, 2013). Hemascein did have trouble on wood-based surfaces, though, where Bluestar and luminol excelled (Seashols et al, 2013).

In 2006, an experiment compared Bluestar to luminol on several different surfaces that were covered in blood and then washed with either a sponge and bleach or Purex laundry detergent (Dilbeck, 2006). The surfaces for this experiment included wood, carpet, vinyl tile,

ceramic tile, blue cotton, and dark blue polyester (Dilbeck, 2006). The results showed that Bluestar outperformed luminol in all cases; the Bluestar glowed brighter for longer periods of time, making it easier to identify than the luminol (Dilbeck, 2006). The results are practical, and helpful to forensics in the field as it advises the use of Bluestar rather than luminol. The experiment also points to the effectiveness of bleach as a cleaner.

A 2017 experiment tested the effectiveness of luminol on latent bloodstains applied to cotton fabric at different concentrations (Cassidy et al, 2017). The experiment used pig's blood, rather than human, due to its similar properties to human blood (Cassidy et al, 2017). While initially the experiment suggested only testing the effectiveness of luminol, Bluestar was also used in comparison (Cassidy et al, 2017). Bluestar proved more effective in finding bloodstains at a lower limit, as compared to luminol (Cassidy et al, 2017).

In 2019, an experiment was run that tested the effectiveness of Bluestar after a surface had been cleaned of blood (Adams et al 2019). The study tested three household cleaners on one surface (Adams et al 2019). The experiment resulted in support that Bluestar was effective regardless of the household cleaner, although Adams, Rancourt and Christensen noted that the experiment could be edited due to a few supposed shortcomings (Adams et al 2019). The experiment was designed with only one surface, ceramic floor tiles. The outcome of this experiment, and others like it, supply information to detectives and forensic scientists in order to allow them to do better jobs. The lack of surface variability, though, proved to be a shortcoming, as it limited the information for detectives and forensic scientists. Only one surface is used, and only three household cleaners. Houses, places of work, and other potential crime scenes have many more surfaces than just ceramic tile. There are also plenty of household cleaners available to the public, name brand or otherwise.

Alternatively, in hiding a crime scene, common household cleaners have also proved capable of breaking down DNA, which is essential in modern court cases. Due to the CSI Effect, a jury expects forensic evidence, like fingerprints and DNA analysis, in most, if not all, cases (Alldredge, 2015). Sodium hypochlorite, or bleach, a common household cleaner, was shown in a 2006 experiment to be the most harmful to DNA of three common household cleaners (Harris et al, 2006). While the other two cleaners had little effect, chlorinated bleach, or hypochlorite-based bleach, continued to deteriorate DNA after the initial point of contact (Harris et al, 2006). There is also an issue with false positives, as provided by hypochlorite-based bleaches (Kent et al, 2003). Hypochlorite-based bleaches give off a chemiluminescence of their own, which causes them to glow in the presence of Bluestar or luminol (Kent et al, 2003).

Clearly, there are holes in the data provided to investigators. Chemiluminescence, as of yet, has no method for quantifiable data which would be helpful in court cases (Polacco et al, 2018). Several of the noted experiments have left out key aspects, notably a lack of surfaces tested that are commonly found at crime scenes and a range of household cleaners that could be used to clean up blood. For instance, only one of the experiments tested wood, but only used bleach as a cleaner (Dilbeck, 2006).

Much like in other fields, visuals can be helpful to detectives and crime scene investigators to know what they're looking for. It is important, then, for detectives and CSI to have visual representation of a plethora of different surfaces, as well as have a working knowledge about how one might cover up bloodstains and what cleaned scenes may look like when exposed to blood detectors. In the prior research, several common surfaces were notably missing, as well as a lack of household cleaner variety. The purpose of this experiment is to

provide those visuals for the surfaces and cleaners, as well as to discover whether either will detrimentally affect the point of blood detectors

Methods

Squares of 10.16cm by 10.16cm white ceramic tile, samples of laminated wood flooring, a sheet of drywall and squares of concrete were purchased from Lowes. The drywall was treated with a coat of paint primer and a coat of white paint before being cut into 10.16cm by 10.16cm squares for experimentation. The surfaces were labelled on the back in sharpie for household cleaners or controls, and whether they were to be tested with luminol or Bluestar®.

Clorox® Regular Bleach$_2$ with CLOROMAX® was used at a concentration of 15.625mL of bleach to a beaker of 500mL of water. Mrs. Meyer's® Multi-Surface Concentrate was used at a solution of 7.812mL of concentrate to a beaker of 500mL of water. Bluestar® was prepared as instructed, mixing a pair of tablets in 125mL of distilled water. The luminol was used as instructed, preparing a dry mixture of 0.2g of luminol to 10g of Arm & Hammer® Super Washing Soda, stirring in 180mL of deionized water, then stirring in 180mL of 3% hydrogen peroxide.

The Dawn Original Dishwashing Liquid and Mr. Clean® Magic Eraser Original were used as received.

Porcine blood obtained from Baker Farms, a local Lynchburg farm, and was stored in a refrigerator at 8°C. For the ceramic tile, the blood was roughly two weeks old. Blood that was roughly a week old was used on the concrete and laminated wood flooring, and the same blood was used a week later on the drywall. The blood was stored in a large plastic container, one roughly 0.946L, or one quart, and the other roughly 3.79L, or one gallon. The quart of blood was

used on the ceramic tiles, and the gallon of blood on the drywall, concrete, and laminated flooring.

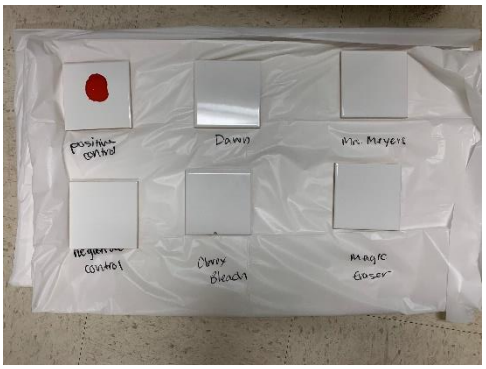

Figure 1: two rows of tiles, post cleaning, before they are sprayed with Bluestar.

Each surface was laid out on a table and approximately 0.5mL of blood was pipetted onto each square and left to dry in a small puddle (figure 1). The time given to dry differed between the surfaces. Ceramic tiles and laminated wood flooring were given 3 hours and 16 minutes. The concrete was allowed to dry for 4 hours and 5 minutes. The drywall was left to dry for roughly 5 hours. The blood was considered dry once it no longer ran when the surface was moved to one side and seemed visibly dry. Once the blood was dry, each square was taken individually to a sink to be washed off.

For the Dawn soap, a line was drawn down the center of a Scotch-Brite sponge, on the soft side. The sponge was placed under a stream of warm water and squeezed a couple of times before being used to scrub off the blood stain using the soft side. Once the bloodstain was visibly removed, the sponge was flipped around to use the opposite end to clear off any bubbles. The sponge was then disposed of and the square was dried with a paper towel, which was also disposed of.

For the Mrs. Meyer's solution, a Scotch-Brite sponge was placed inside the 500mL beaker to soak. Once the square marked 'Mrs. Meyer's' was brought over, the sponge was taken out of the 500mL beaker and excess water was squeezed out over the square. One end of the sponge was used to scrub away the bloodstain, on the soft side, and the other end was used to wipe away bloody suds. The square was dried off with a paper towel and then the towel and sponge were disposed of.

For the bleach, a Scotch-Brite sponge was placed inside the 500mL beaker to soak. Once the square marked ‘Clorox bleach’ was brought over, the sponge was taken out of the 500mL beaker and excess water was squeezed out over the square. One end of the sponge was used to scrub away the bloodstain, on the soft side, and the other end was used to wipe away the excess watery blood. The square was dried off with a paper towel and then the towel and sponge were disposed of.

For the Magic Eraser, a small amount of water was poured over the square. The Magic Eraser was used to scrub off the bloodstain until no longer visible, and then flipped over to wipe off any excess watery blood. The square was dried with a paper towel and the towel and Magic Eraser were disposed of.

In order to avoid contamination, a plastic table cover was spread over the floor and spots were labelled with a Sharpie (figure 1). Visual observations were conducted in a windowless room with the lights off after the investigator was allowed to acclimatize for 5 minutes. The luminol solution was sprayed onto one of each of the surfaces. The Bluestar® solution was sprayed onto one of each of the surfaces.

Results

As the control in order to work out the kinks, ceramic tiles were tested first. For the first and second round of the Bluestar®, the detector reacted with the positive control, Dawn, Mrs. Meyer’s®, and Magic Eraser (table 1). For the first round of the luminol, the detector reacted with the positive control, Dawn, Mrs. Meyer’s®, Clorox bleach, and Magic Eraser (table 2). The second round was the same with the exception of the Clorox bleach, which didn’t react with the luminol (table 2).

Bluestar® on Ceramic Tile

	Positive Control	Negative Control	Dawn	Mrs. Meyer's®	Clorox® bleach	Magic Eraser
Round 1	reactive	nonreactive	reactive	reactive	nonreactive	reactive
Round 2	reactive	nonreactive	reactive	reactive	nonreactive	reactive

Table 1: After the tiles were cleaned and sprayed with Bluestar®, the cleaners were either marked reactive or nonreactive depending on whether they glowed.

Luminol on Ceramic Tile

	Positive Control	Negative Control	Dawn	Mrs. Meyer's®	Clorox® bleach	Magic Eraser
Round 1	reactive	nonreactive	reactive	reactive	reactive	reactive
Round 2	reactive	nonreactive	reactive	reactive	nonreactive	reactive

Table 2: After the tiles were cleaned and sprayed with luminol, the cleaners were either marked reactive or nonreactive depending on whether they glowed.

During the first Bluestar® round, the Dawn was visibly the brightest, followed by the Mrs. Meyer's® solution, the Magic Eraser, and the dimmest being the Clorox® bleach, which didn't react at all. The second round of Bluestar®, the Magic Eraser glowed the brightest, followed by the Mrs. Meyer's® solution, the Dawn, and the Clorox® bleach, which once again didn't glow at all. During the first luminol round, the Magic Eraser was visibly the brightest, followed by the Dawn, the Mrs. Meyer's® solution, and the dimmest being the Clorox® bleach. The second round of luminol, the Magic Eraser glowed the brightest, followed by the Mrs. Meyer's® solution, the Dawn, and the Clorox® bleach, which didn't glow at all.

Concrete was the second surface tested. Due to the porous nature of the concrete, the blood was not completely washed out, which meant that all four cleaners were reactive to both blood detectors (table 3, table 4).

For the Bluestar® rounds, the Dawn was visibly the brightest for all three trials, and the dimmest were the Clorox® bleach and the Mrs. Meyer's® solution. Luminol had some more

diversity, with Dawn and the Magic Eraser having the brightest visual chemiluminescence, and the Mrs. Meyer's® solution being the dimmest for all three trials.

Bluestar® on Concrete

	Positive Control	Negative Control	Dawn	Mrs. Meyer's®	Clorox® bleach	Magic Eraser
Round 1	reactive	nonreactive	reactive	reactive	reactive	reactive
Round 2	reactive	nonreactive	reactive	reactive	reactive	reactive
Round 3	reactive	nonreactive	reactive	reactive	reactive	reactive

Table 3: After the concrete was cleaned and sprayed with Bluestar®, the cleaners were either marked reactive or nonreactive depending on whether they glowed.

Luminol on Concrete

	Positive Control	Negative Control	Dawn	Mrs. Meyer's®	Clorox® bleach	Magic Eraser
Round 1	reactive	nonreactive	reactive	reactive	reactive	reactive
Round 2	reactive	nonreactive	reactive	reactive	reactive	reactive
Round 3	reactive	nonreactive	reactive	reactive	reactive	reactive

Table 4: After the concrete was cleaned and sprayed with luminol, the cleaners were either marked reactive or nonreactive depending on whether they glowed.

The only reactive element for laminated wood floorings were the positive controls for both blood detectors.

Bluestar® on Laminated Wood Flooring

	Positive Control	Negative Control	Dawn	Mrs. Meyer's®	Clorox® bleach	Magic Eraser
Round 1	reactive	nonreactive	nonreactive	nonreactive	nonreactive	nonreactive
Round 2	reactive	nonreactive	nonreactive	nonreactive	nonreactive	nonreactive
Round 3	reactive	nonreactive	nonreactive	nonreactive	nonreactive	nonreactive

Table 5: After the laminated flooring was cleaned and sprayed with Bluestar®, the cleaners were either marked reactive or nonreactive depending on whether they glowed.

Luminol on Laminated Wood Flooring

	Positive Control	Negative Control	Dawn	Mrs. Meyer's®	Clorox® bleach	Magic Eraser
Round 1	reactive	nonreactive	nonreactive	nonreactive	nonreactive	nonreactive
Round 2	reactive	nonreactive	nonreactive	nonreactive	nonreactive	nonreactive
Round 3	reactive	nonreactive	nonreactive	nonreactive	nonreactive	nonreactive

Table 6: After the laminated flooring was cleaned and sprayed with luminol, the cleaners were either marked reactive or nonreactive depending on whether they glowed.

The drywall was found to be reactive in all cases except the negative control. During the first Bluestar® round, the Clorox® bleach was visibly the brightest, followed by the Magic Eraser solution, the Mrs. Meyer's® solution, and the dimmest being the Dawn. The second round of Bluestar®, the Clorox® bleach glowed the brightest, followed by the Magic Eraser, the Mrs. Meyer's® solution, and the Dawn. The third round of Bluestar®, the Clorox® bleach was visibly the brightest, followed by the Magic Eraser solution, the Dawn, and the dimmest being the Mrs. Meyer's® solution.

While there was a technological malfunction that prevented pictures being taken of the luminol trials, observations were written down. During the first luminol round, the Clorox® bleach was visibly the brightest, followed by the Magic Eraser, the Mrs. Meyer's® solution, and the dimmest being the Dawn. The second round of luminol, the Magic Eraser glowed the brightest, followed by the Clorox® bleach, the Dawn, and lastly the Mrs. Meyer's® solution. The third round of luminol saw the Clorox® bleach glow the brightest, followed by the Magic Eraser, then the Dawn, and then the Mrs. Meyer's® solution.

Bluestar® on Drywall

	Positive Control	Negative Control	Dawn	Mrs. Meyer's®	Clorox® bleach	Magic Eraser
Round 1	reactive	nonreactive	reactive	reactive	reactive	reactive
Round 2	reactive	nonreactive	reactive	reactive	reactive	reactive
Round 3	reactive	nonreactive	reactive	reactive	reactive	reactive

Table 7: After the drywall was cleaned and sprayed with Bluestar®, the cleaners were either marked reactive or nonreactive depending on whether they glowed.

Luminol on Drywall

	Positive Control	Negative Control	Dawn	Mrs. Meyer's®	Clorox® bleach	Magic Eraser
Round 1	reactive	nonreactive	reactive	reactive	reactive	reactive
Round 2	reactive	nonreactive	reactive	reactive	reactive	reactive
Round 3	reactive	nonreactive	reactive	reactive	reactive	reactive

Table 8: After the drywall was cleaned and sprayed with luminol, the cleaners were either marked reactive or nonreactive depending on whether they glowed.

Discussion

The ceramic tile was used as a litmus test, in order to determine how the blood would be applied to the surfaces, how long it would take to dry, and if the luminol solution worked. The blood applied took a bit longer than anticipated in order to dry. The luminol solution was tricky to work out, at first, because the recipe on the pamphlet that came with the powder called for ingredients I didn't have access to. After some light research, I found a mixture that worked and applied it to the rest of the experiment.

The laminated wood flooring was surprisingly non-reactive. Considering the ridges and valleys in the faux wood, it was interesting that the blood was so effectively cleaned off. I

expected it to react more like the concrete had, with pockets of blood, but everything was cleaned off with relative ease.

As for the drywall, while the blood was washed off, it left behind a visible stain on the squares. Despite the household cleaners, the stains did not come off, even with the bleach mixture. Without an extra coat of paint, I doubt the stain would ever truly be removed.

The results of the experiment are useful to fieldwork. The observations of blood on these surfaces would be helpful at a crime scene, as well as expected visual glow. For the most part, Bluestar's chemiluminescence remained brighter for longer periods of time when compared to luminol.

The experiment could benefit from a machine that could provide quantifiable data in the measurement of chemiluminescence. Such a machine was unavailable to this experiment. A greater variety of surfaces and cleaners would also be beneficial, as it would provide more data, visibly and quantifiably, for investigators. Since the experiment was done over a matter of days, the blood used was not very fresh, and changes in blood consistency could affect the chemiluminescence or the blood's ability to be cleaned off of a surface. For further experimentation, and incorporating elements from past experimentation, the methods could be changed to include diluted blood and smaller amounts of blood with more rounds of cleaning. The diluted blood and multiple rounds of cleaning would be harder to pick up by blood detectors.

The results also have a bit of a nefarious side as well. The first part of getting away with murder would be to not commit one in the first place. Based on the evidence, however, the next part would be choosing a surface and a cleaner that would best cover up the crime.

Conclusion

Based on the evidence, the best way to commit a violent crime would be on a surface made of ceramic tile or laminated flooring, due to their overall lack of staining or residual blood, as well as the ease of cleaning. When taking into consideration the household cleaners in this experiment, the best cleaners to cover up the crime scene would be either Clorox® bleach or Mrs. Meyer's® solution. Drywall and concrete should be avoided due to their porous and stainable natures, which would reveal blood residue before a blood detector is applied, and Dawn and Magic Erasers are inadequate at cleaning a crime scene.

References

Adams, J. L., Rancourt, E. D., & Christensen, A. M. (2019a). The Effect of Household Oxidizing Cleaners on Chemiluminescence of Blood Using Bluestar. *Journal of Forensic Sciences; J Forensic Sci, 64*(3), 869-872. 10.1111/1556-4029.13914

Alldredge, J. (2015). The CSI Effect and Its Potential Impact on Juror Decisions. *Themis: Research Journal of Justice Studies and Forensic Science,* 3(1)10.31979/THEMIS.2015.0306

Cassidy, B. M., Lu, Z., Martin, J. P., Tazik, S. K., Kellogg, K. W., DeJong, S. A., Belliveau, E. O., Kilgore, K. E., Ervin, S. M., Meece-Rayle, M., Abraham, A. M., Myrick, M. L., & Morgan, S. L. (2017). A quantitative method for determining a representative detection limit of the forensic luminol test for latent bloodstains. *Forensic Science International; Forensic Sci Int, 278,* 396-403. 10.1016/j.forsciint.2017.06.031

Dilbeck, L. (2006). Use of Bluestar Forensic in lieu of luminol at crime scenes. *Journal of Forensic Identification, 56*(5), 706.

Edward, T. G. (2017). Ability of Bluestar Forensics and Luminol to Reveal Latent Bloodstains Exposed to Extreme Outdoor Conditions. *Journal of Forensic Identification, 67*(4), 581-599.

Grispino, R. (1990). *The Effect of Luminol on the Serological Analysis of Dried Human Bloodstains*. US Department of Justice.

Harris, K. A., Thacker, C. R., Ballard, D., & Court, D. S. (2006). The effect of cleaning agents on the DNA analysis of blood stains deposited on different substrates. International Congress Series, 1288, 589-591. https://doi.org/10.1016/j.ics.2005.09.171

Huntress, E. H., Stanley, L. N., & Parker, A. S. (1934). The oxidation of 3-aminophthalhydrazide ("luminol") as a lecture demonstration of chemiluminescence. *Journal of Chemical Education, 11*(3), 142. 10.1021/ed011p142

Kent, E., Elliot, D., & Miskelly, G. (2003). Inhibition of Bleach-Induced Luminol Chemiluminescence. *Journal of Forensic Sciences, 48*(1), 1-4. 10.1520/JFS2002105

Lowis, T., Leslie, K., Barksdale, L. E., & Carter, D. O. (2012). Determining the Sensitivity and Reliability of Hemascein. *Journal of Forensic Identification, 62*(3), 204-214. https://www.ojp.gov/ncjrs/virtual-library/abstracts/determining-sensitivity-and-reliability-hemascein

Muralidhar, M. (2019). *Comparison of Chemiluminescent and Fluorescent Blood Detection Kits* (M.S.). Available from ProQuest Dissertations & Theses Global. (2284673715). https://ezproxy.lynchburg.edu/login?url=https://www-proquest-com.ezproxy.lynchburg.edu/docview/2284673715?accountid=12198

Oldfield, C., Morgan, R. M., Miles, H. F., & French, J. C. (2018a). The efficacy of luminol in detecting bloodstains that have been washed with sodium percarbonate and exposed to environmental conditions. *Australian Journal of Forensic Sciences, 50*(4), 345-354. 10.1080/00450618.2016.1264478

Polacco, S., Wilson, P., Illes, M., & Stotesbury, T. (2018). Quantifying chemiluminescence of the forensic luminol test for ovine blood in a dilution and time series. *Forensic Science International; Forensic Sci Int, 290*, 36-41. 10.1016/j.forsciint.2018.06.026

Quinones, I., Sheppard, D., Harbison, S., & Elliot, D. (2007). Comparative Analysis of Luminol Formulations. *Canadian Society of Forensic Science Journal, 40*(2), 53-63. 10.1080/00085030.2007.10757151

Seashols, S. J., Cross, H. D., Shrader, D. L., & Rief, A. (2013). A Comparison of Chemical Enhancements for the Detection of Latent Blood. *Journal of Forensic Sciences, 58*(1), 130-133. 10.1111/j.1556-4029.2012.02259.x

Vineyard, A. R., Hazelrigg, E. J., Ehrhardt, C. J., & Connon, C. C. (2019). Evaluation of Bluestar® Forensic Magnum and Other Traditional Blood Detection Methods on Bloodstained Wood Subjected to a Variety of Burn Conditions. *Journal of Forensic Sciences; J Forensic Sci, 64*(3), 878-887. 10.1111/1556-4029.13946

Yang, J. (2019). *Crime Scene Blood Evidence Detection Using Spectral Imaging* (Ph.D.). Available from ProQuest Dissertations & Theses Global. (2311052226). https://ezproxy.lynchburg.edu/login?url=https://www-proquest-com.ezproxy.lynchburg.edu/docview/2311052226?accountid=12198