Journal of Occupational and Environmental Hygiene
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713657996

Case Studies

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First published on: 23 August 2010

To cite this Article Fent, Kenneth W.(2010) 'Case Studies', Journal of Occupational and Environmental Hygiene, 7: 10, D73 — D78, First published on: 23 August 2010 (iFirst)
To link to this Article: DOI: 10.1080/15459624.2010.509843
URL: http://dx.doi.org/10.1080/15459624.2010.509843

Journal of Occupational and Environmental Hygiene, 7: D73–D78
ISSN: 1545-9624 print / 1545-9632 online
DOI: 10.1080/15459624.2010.509843

Case Studies
Evaluation of Chemical Hazards at a Criminal Investigation Section of a Police Department

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The findings and conclusion in this report are those of the author and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation at a municipal police department in response to a request submitted by management concerning chemical exposures encountered by criminalists during criminal investigation procedures. At the time of the evaluation, several methods were used by criminalists for processing criminal evidence. Latent fingerprints were identified using one of three methods: (1) fingerprint powder dusting, (2) ninhydrin solution spraying, and (3) super glue fuming. Latent blood was detected by luminol solution spraying.

When fingerprint powder is dusted over evidence or on surfaces at a crime scene, the dust adheres to residual oils that fingers leave behind, thereby revealing ridge patterns, or fingerprints. When sprayed on evidence, ninhydrin reacts with residual amino acids that fingers leave behind to form a deep blue or purple fingerprint.[1] In the super glue "fuming" method, ethyl cyanoacrylate, the main ingredient in super glue, is heated inside a chamber containing evidence. The ethyl cyanoacrylate vapors and atmospheric moisture react with fingerprint residues to form a white polymer.[1] When luminol solution is sprayed onto latent blood, the iron in the hemoglobin catalyzes the reaction between luminol and other components of the solution (including hydrogen peroxide) to produce chemiluminescence, which refers to the emission of light from a chemical reaction.[2]

Our evaluation included observing methods used by criminalists and collecting general area and personal breathing zone (PBZ) air samples for the different chemicals they use. We also compared the pressure differentials in the crime lab with adjacent office areas and measured the airflow and capture efficiencies of the local exhaust ventilation (LEV) systems used in the crime lab.

OBSERVATIONS

Fingerprint Powder Dusting

The black fingerprint powder contained carbon black. One criminalist dusted the fingerprint powder onto evidence using the downdraft table in the crime lab. This criminalist wore nitrile gloves and an N95 filtering facepiece respirator (AOSafety Pleats Plus; 3M, St. Paul, Minn.). Two criminalists dusted fingerprint powder onto an automobile inside the garage (Figure 1). One of them wore cloth coveralls, nitrile gloves, and a half-mask elastomeric respirator with type P100 particulate cartridges (Comfo Respirator; MSA, Pittsburgh, Pa.). The other criminalist wore Tyvek coveralls (DuPont, Wilmington, Del.), nitrile gloves, and an AOSafety Pleats Plus N95 filtering facepiece respirator. All the garage doors were closed during fingerprint powder dusting. Magnetic fingerprint powders containing iron were applied to evidence

FIGURE 1. Fingerprint powder dusting.

under the overhead exhaust hood in the crime lab; however, we did not sample the air during this process.

Ninhydrin Solution Spraying

The ninhydrin solution, containing ethyl acetate, acetone, and dissolved ninhydrin powder crystals (2,2-dihydroxyindane-1,3-dione) was mixed outside the chemical fume hood in the crime lab. After mixing, two criminalists sprayed ninhydrin solution onto evidence under the chemical fume hood. After spraying, the ninhydrin solution is allowed to dry on the evidence before being transferred from the chemical fume hood to the unventilated ninhydrin development cabinet. Both criminalists wore nitrile gloves during ninhydrin spraying and evidence transfer, and one criminalist wore a half-mask respirator with combination organic vapor/P95 filter cartridges (Dual Cartridge Respirator; 3M).

Super Glue Fuming

One criminalist used a small fuming chamber (~6 ft^3), and two criminalists used a larger fuming chamber (~25 ft^3). Because the Plexiglas doors on both fuming chambers had become coated with super glue residue and were no longer transparent, the doors were occasionally opened a few inches during the super glue fuming so the criminalists could view the fingerprint development process. The fuming chamber exhaust fans remained off during this time and were turned on only at the end of the fuming cycle to evacuate the chambers. Both criminalists involved in the super glue fuming wore nitrile gloves and the one of following respirators: MSA Comfo Respirator with organic vapor cartridge or 3M Dual Cartridge Respirator with combination organic vapor/P95 filter cartridge.

Luminol Solution Spraying

The aqueous luminol solution contains sodium carbonate, sodium perborate tetrahydrate, and luminol (5-amino-2,3-dihydro-1,4-phthalazine-dione). Sodium carbonate is a base, and sodium perborate tetrahydrate produces hydrogen peroxide in water. One criminalist, wearing Tyvek coveralls and nitrile gloves, mixed the luminol solution in a spray bottle and then sprayed the solution onto mock evidence inside the garage.

ASSESSMENT

Air Sampling

Although we could not sample every chemical used by criminalists, we sampled those with the greatest potential for exposure and/or the greatest potential to cause adverse health effects. We measured criminalists' PBZ concentrations of carbon black during fingerprint powder dusting, ethyl acetate during ninhydrin solution spraying, and ethyl cyanoacrylate during super glue fuming. Due to the intermittent nature of the criminalists' work, the PBZ samples were collected during specific tasks rather than the entire work shift. We also measured the concentration of hydrogen peroxide in the headspace of the luminol solution spray bottle. In addition, we conducted area air sampling for ethyl acetate and ethyl cyanoacrylate for the entire work shift (~8 hr). Figure 2 shows a schematic of the area air sampling locations.

Carbon black was sampled using tared 37-mm diameter polyvinyl chloride (PVC) filters at a flow rate of 2 L/min and analyzed using NIOSH Method 5000.[3] Ethyl acetate was sampled using charcoal tubes (100 mg/50 mg) at a flow rate of 200 cc/min and analyzed using NIOSH Method 1457.[3] Ethyl cyanoacrylate was sampled using phosphoric acid treated XAD-7 tubes at a flow rate of 200 cc/min and analyzed using OSHA Method 55.[4] Sampling for hydrogen peroxide was conducted using colorimetric indicator tubes (Drager, Lubeck, Germany) and a hand-held Drager Accuro pump.

Ventilation Measurements

A VelociCalc Plus anemometer (TSI Inc., Shoreview, Minn.) was used to measure air velocity through the LEV systems. Air velocity measurements were recorded at approximately 4-inch intervals along the face of the LEV system or another opening where air was being drawn (e.g., open baffles on the super glue fuming chambers). Capture efficiency of the LEV systems was evaluated using irritant "smoke" tubes (Gastec Corporation, Kanagawa, Japan). To visualize the capture efficiency, an aerosol "smoke" was generated in the work area where contaminants were to be captured or contained. Smoke tubes were also used to determine pressure differences by generating smoke near the doors of the rooms being evaluated and observing whether the smoke was drawn into the room (negative pressure) or pushed out of the room (positive pressure).

RESULTS

Table I presents the PBZ concentrations for the different tasks performed by the criminalists. Because short-term or ceiling occupational exposures limits (OELs) did not exist for the chemicals we sampled in this evaluation, the air

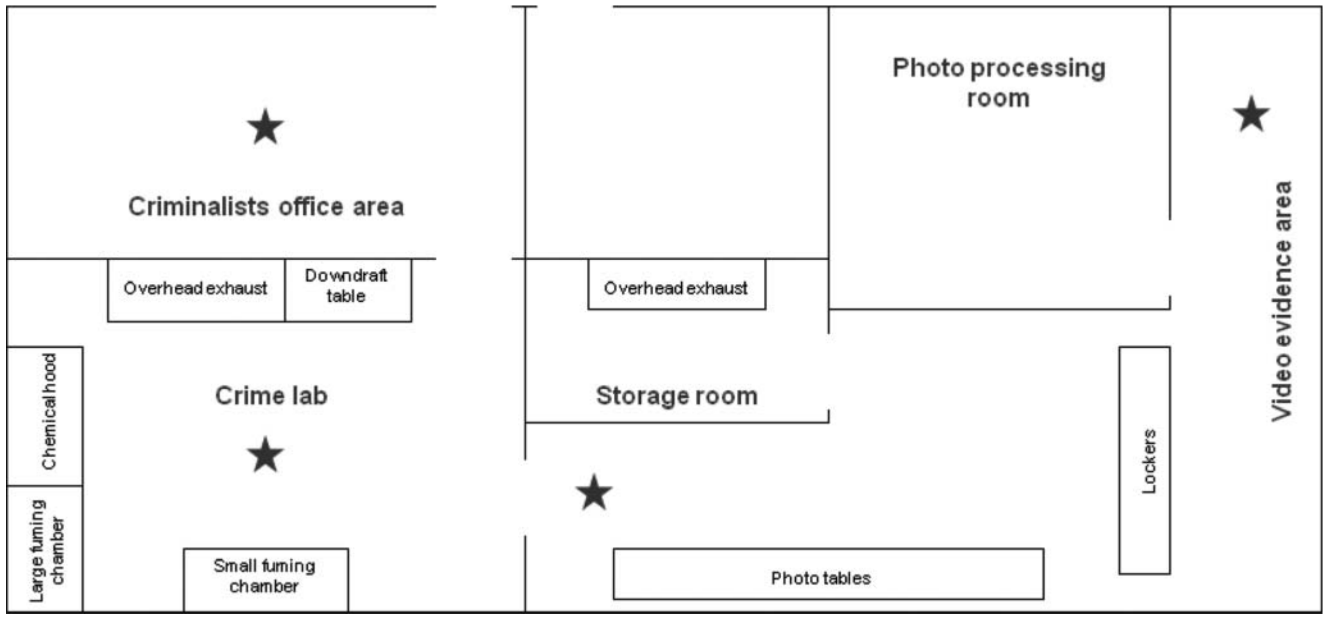

FIGURE 2. Area air sampling locations for ethyl acetate and ethyl cyanoacrylate (denoted with stars).

sampling results obtained from task-based (14–199 min) samples were instead compared with OELs corresponding to 8-hr time-weighted average (TWA) concentrations.

The carbon black used in the fingerprint powder was commercial grade and did not contain polycyclic aromatic hydrocarbons (PAHs). Hence, the NIOSH recommended exposure limit for carbon black containing PAHs (0.1 mg/m^3) does not apply. All the PBZ concentrations were below applicable OELs.

The area air sampling results are shown in Table II. Ethyl acetate vapors from the ninhydrin spraying were detected throughout the building. Ethyl cyanoacrylate vapors from the super glue fuming were detected in the crime lab but not in adjacent labs or office areas. Using ventilation smoke tubes, we found that the crime lab was under positive pressure relative to adjacent areas, which likely contributed to the migration of ethyl acetate vapors from the crime lab to other areas of the building.

Table III summarizes the air velocity measurements and smoke tube testing on the LEV systems used in the crime lab. Smoke tube testing demonstrated effective capture of smoke for all the LEV systems except the overhead exhaust hood and super glue fuming chambers when the doors were opened 1 inch to view the fingerprint development. In addition, the high efficiency particulate filter used in the downdraft table needed replacement because we observed evidence of breakthrough (fingerprint powder on the back of the filter). Likewise, the combination particulate and organic vapor filter used in the small super glue fuming chamber needed replacement because ethyl cyanoacrylate vapors were measured in the exhaust from this chamber.

DISCUSSION

All PBZ concentrations were below applicable OELs and therefore represent conditions under which nearly all employees may be exposed over a working lifetime without adverse health effects.[5] However, the PBZ concentrations of carbon black measured during fingerprint powder dusting to an automobile approached the OEL of 3.5 mg/m^3, suggesting that criminalists' exposures to carbon black may approach the OEL if this activity was done over an entire workday (8 hr). According to our interviews with the criminalists, fingerprint powder dusting may be performed for more than 8 hr at large crime scenes. Thus, we cannot say with confidence that exposures to carbon black during crime scene processing do not exceed the OELs on some days.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) provides recommendations and guidance for the evaluation of laboratory LEV systems.[6] Generally, ASHRAE does not specify air velocity rates for LEV systems. Instead, they rely largely on visualization methods and tracer gas tests to ensure that contaminants are being captured. Smoke tube testing is one simple way of evaluating the capture efficiency of LEV systems for gases and vapors. In this evaluation, the smoke we generated was not captured efficiently by either the overhead exhaust hood or by the super glue fuming chambers when their doors were opened 1 inch.

The overhead exhaust hoods were used sparingly during our investigation (e.g., a few minutes of magnetic fingerprint powder dusting to evidence). The super glue fuming chambers, on the other hand, were used by three different criminalists at

TABLE I. Personal Breathing Zone Sampling Results

Analyte	Process Description	Sample Time (min)	Concentration	OEL
Carbon black	Fingerprint powder dusting to evidence on the downdraft table	120	ND[A]	3.5 mg/m^3[B,C,D]
	Fingerprint powder dusting to an automobile in a garage	30	0.88 mg/m^3	
	Fingerprint powder dusting to an automobile in a garage	31	2.3 mg/m^3	
Ethyl acetate	Spraying ninhydrin under the fume hood and mixing ninhydrin outside the fume hood	170	0.92 ppm	400 ppm[B,C,D]
	Spraying ninhydrin under the fume hood	14	13 ppm	
Ethyl cyanoacrylate	Developing fingerprints in the large fuming chamber	169	ND[E]	0.2 ppm[D]
	Developing fingerprints in the large fuming chamber	143	ND[E]	
	Developing fingerprints in the small fuming chamber	199	0.022 ppm	
Hydrogen peroxide	Spraying luminol onto mock latent blood (headspace sample)	3	ND[F]	1 ppm[B,C,D]

Notes: ND = nondetectable.
[A]Below the minimum detectable concentration of 0.48 mg/m^3.
[B]OSHA exposure limit.
[C]NIOSH recommended exposure limit.
[D]ACGIH® threshold limit value.
[E]Below the minimum detectable concentration of 0.014 ppm.
[F]No color change on the colorimetric indicator tubes. Standard range of measurement is 0.1 to 3 ppm.

various times throughout the workday. The Plexiglas doors of the fuming chambers were opened a few inches so the criminalists could view the progress of the fingerprint development. The exhaust fans in the super glue fuming chambers remained off during this time, but even if they had been turned on, our findings suggest that the air velocity would be inadequate to efficiently capture ethyl cyanoacrylate vapors. This is probably one reason why we measured detectable concentrations of ethyl cyanoacrylate vapors in the crime lab. The other reason was that the combination particulate and organic vapor filter in the small super glue fuming chamber had surpassed its useful service life.

The ANSI/AIHA® Standard Z9.5-2003 specifies that most chemical fume hoods can be operated effectively at 80–100 ft/min; however, operating chemical fume hoods below 60 ft/min is not recommended.(7) The air velocity we measured through the chemical fume hood was below the minimum level when the sash was fully opened (57 ft/min) but within the recommended range when the sash was half opened (89 ft/min). The hood was operated at both sash heights during our evaluation. According to our smoke tube testing, the chemical fume hood was efficiently capturing contaminants at both sash heights. Nevertheless, keeping the sash at half opened height or lower during use should improve the capture efficiency. Irrespective of the chemical fume hood capture efficiency, the most likely reasons that ethyl acetate was detected in the crime lab were that (1) the criminalists mixed ninhydrin solution outside the chemical fume hood, and (2) they transferred the ninhydrin-sprayed evidence to the development cabinets before the evidence had completely dried.

TABLE II. Area Air Sampling Results

Location	Ethyl Acetate (ppm)	Ethyl Cyanoacrylate (ppm)
Crime lab	0.30	0.008
Criminalist office area	0.14	ND
Photo tables	0.14	ND
Video evidence area	0.09	ND

Note: ND, nondetectable (below the minimum detectable concentration of 0.0002 ppm)

TABLE III. Evaluation of the LEV Systems Used in the Crime Lab

Type of LEV system	Area of Face (ft^2)	Air Velocity (ft/min)		Effective Capture of Smoke?
		Range	Mean	
Chemical fume hood				
Fully opened sash	9.4	36–70	57	Yes
Half opened sash	4.7	37–160	89	Yes
Large super glue fuming chamber				
Closed door/open baffle	0.3	500–540	520	Yes
Door opened 1 inch	6.5	5–25	15	No
Small super glue fuming chamber				
Closed door/open baffle	0.3	100–110	107	Yes
Door opened 1 inch	2.6	1–4	2.5	No
Fingerprint powder downdraft table	3.0	40–90	62	Yes
Overhead exhaust hood[A]	6.7	13–120	72	No

Note: Air velocity measurements were taken at the face or opening where air was being drawn, while smoke tube testing was conducted at the work area where contaminants were being captured or contained.
[A]The mean capture velocity at the work area (4 ft below the hood) was 3 ft/min.

CONCLUSION

The PBZ air sampling identified no exposures to any measured chemicals used by criminalists that were over applicable OELs. Nevertheless, an opportunity exists for improving work conditions both inside and adjacent to the crime lab. Our findings suggested inadequacies with the LEV in super glue fuming chambers and the overhead exhaust hood currently being used by criminalists. In addition, the potential for overexposure to carbon black exists if fingerprint powder dusting were to be performed for an entire workday. Because procedures and exposures are likely to vary among police departments throughout the country, further exposure assessments of criminal investigation units are warranted. The findings from this evaluation suggest a need for occupational health and safety education and training for criminalists and corresponding law enforcement management. The following recommendations were provided to the police department management to better protect their criminalists.

RECOMMENDATIONS

Engineering Controls

1. Replace air filters used in the LEV systems routinely according to manufacturers' specifications to ensure proper filtration of contaminants.
2. Maintain the crime lab under negative pressure relative to the adjacent areas. Specific guidance on ventilation for laboratories is provided in Chapter 14 of the *ASHRAE Handbook: HVAC Applications*.[6]
3. Increase the airflow through the overhead exhaust hoods to ensure efficient capture velocity. Under their current design, these hoods should be used only for processes involving volatile or semivolatile chemicals that cannot otherwise be performed under the chemical fume hood (e.g., objects that are too large for the fume hood). These hoods should not be used for fingerprint powder dusting as the upward airflow could actually draw the dust into the criminalists' PBZs. The downdraft table or a new slot hood would better control the fingerprint powder.
4. Replace super glue fuming chambers with ones that have the following safety features: (1) glass window enclosures with locking mechanisms that cannot be opened during use until the chambers are fully evacuated; (2) exhaust systems that vent to the outdoors and/or contain organic vapor filtration systems; (3) laboratory determined filter change out schedule based on number of cycles or end of service life indicator; and (4) counters that display the number of cycles run since last filter changeout.

Administrative Controls

1. Handle chemicals (pouring, mixing, spraying, etc.) only under the chemical fume hood. In addition, evidence sprayed with ninhydrin solution should be allowed to dry completely before being placed into the development cabinet.
2. Test and certify the chemical fume hood annually. The sash of the chemical fume hood should be maintained at half-opened height or lower during use to further improve its performance. Marking the half-opened height will serve as a reminder to operate the fume hood at that

height. An alarm may also be used to warn operators of insufficient air velocity.

3. Develop a written laboratory health and safety plan that describes workplace hazards, standard operating procedures, engineering controls, and personal protective equipment required for each method criminalists use to process evidence. For guidance, refer to the International Association for Identification (IAI) *Safety Guidelines*[8] and the Federal Bureau of Investigation *Handbook of Forensic Services*.[9] This plan should be updated regularly (e.g., annually) or as needed.
4. Organize a health and safety committee consisting of management and employee representatives who meet regularly to address health and safety concerns and update the laboratory health and safety plan.
5. Collect carbon black air samples during fingerprint powder dusting at a crime scene to estimate PBZ concentrations over an entire work shift and determine that exposures are above or below the OEL of 3.5 mg/m^3.

Personal Protective Equipment

1. Use nitrile gloves for all the criminal investigation procedures.
2. Use chemical resistant clothing and safety glasses or goggles when working with chemicals and powders that have the potential to contact the skin or eyes.
3. Consider using N95 filtering facepiece respirators voluntarily, particularly where engineering controls cannot easily be implemented, such as during fingerprint powder dusting of automobiles in a garage or at a crime scene. Although a written respiratory protection program is not mandatory for voluntary use of filtering facepiece respirators, provide criminalists with a copy of Appendix D, "Information for Employees Using Respirators When not Required under the Standard," of the OSHA Respiratory Protection Standard.[10]

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