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Control of Ethyl Methacrylate Exposures During the Application of Artificial Fingernails

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In 1990 six cases of physician-diagnosed occupational asthma in cosmetologists working with artificial fingernails prompted the Colorado Department of Health to request the assistance of National Institute for Occupational Safety and Health (NIOSH) researchers in the evaluation and control of nail salon technician exposure. A commercially available recirculating downdraft table with charcoal filters was purchased and evaluated. Researchers from NIOSH made modifications to the table that included increasing the downdraft air volume; enlarging the plenum for more consistent airflow rates at the face of the table; removing the charcoal filters while incorporating a ventilation system to the outdoors; and putting an extension around the duct leading to the perforated plate at the downdraft face of the table. An evaluation was performed using the following two configurations: the modified table with the downdraft ventilation on (vented) and without the downdraft ventilation on (unvented). Each of the two configurations was sampled for 3 days in random order. Testing included the use of XAD-2 solid sorbent tubes for determining ethyl methacrylate and methyl methacrylate concentrations. Relative concentrations of organics were examined and used to analyze work practices. The geometric mean ethyl methacrylate exposure for personal breathing zone samples when using the modified table for approximately 6 hours was 0.6 ppm; when using the unventilated conventional table, the geometric mean exposure was 8.7 ppm. The difference in the values is statistically significant ($p=0.0045$). Methyl methacrylate concentrations were nondetectable on all sorbent tubes.

Keywords: cosmetologists, cosmetology, ethyl methacrylate, ventilation

In 1990 six cases of occupational asthma in cosmetologists working with artificial fingernails prompted the Colorado Department of Health to request the assistance of the National Institute for Occupational Safety and Health (NIOSH) researchers in the evaluation and control of nail salon technician exposure. NIOSH researchers initiated a project to reduce

the risk of hazardous exposure to nail salon technicians. Since the etiology of the disease cases (asthma) is unknown, employee exposures to ethyl and methyl methacrylate were quantified and used as an index of control. Employee exposures to ethyl and methyl methacrylate when using an unventilated manicure table were compared with those measured when a downdraft manicure table was used.

The technique for application of artificial fingernails was developed perhaps as early as the late 1950s, but became popular in the early 1970s when manicurists began applying methyl methacrylate dental acrylic to fingernails to strengthen natural nails or create artificial nails.⁽¹⁾ Methyl

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methacrylate was banned for use in nail products in 1974 by the U.S. Food and Drug Administration⁽²⁾ because of health effects, including dermatitis in both customers and technicians; it has been replaced with ethyl methacrylate. In 1993 there were 190,000 nail technicians, up 9% from 1992. Most salons have little or no controls for hazardous substances used during artificial nail application, and most nail technicians are not concerned about the chemical hazards.⁽³⁾

HEALTH EFFECTS

Many products are used during the application of artificial nails, including the color coat remover, the liquid and powder of the artificial nails, the adhesives, primers, and color coats. Even though methyl methacrylate is banned for use in nail products, researchers from NIOSH found at least trace amounts in 15 of 25 random bulk samples of the powder and liquid components.⁽⁴⁾ Methyl methacrylate has been found to cause dermatitis⁽⁵⁾ and is an eye and mucus membrane irritant; there are also cases of methyl methacrylate causing occupational asthma.⁽⁶⁾ High concentrations may cause central nervous system depression and unconsciousness;⁽⁷⁾ it is also a potent skin sensitizer.⁽⁸⁾ The toxic effects are due to the monomer (liquid); the polymer (solid) appears to be inert.⁽⁹⁾ There is evidence that ethyl methacrylate is toxicologically similar to methyl methacrylate.⁽¹⁰⁾ Both are potent skin sensitizers, and industrial hygiene recommendations are the same for both compounds.⁽⁸⁾ Previous studies have shown that technicians' exposures during artificial nail application are below recommended limits for several potentially hazardous substances.⁽¹¹⁻¹³⁾ It is possible that reported asthma cases may be occurring even when exposures are below the recommended limits.

PROCESS DESCRIPTION

During the application of artificial nails, old color coats are removed, and the natural nail surface is filed to create a rough surface for better adhesion. The natural nail surface is then sanitized, and a dehydrating liquid and a primer are applied to the nail to promote adhesion. After the preparation of the natural fingernail, there are two major types of artificial nail applications:

- Sculptured nails often are preferred if a client's natural nails are very short. These are formed over the natural nail, and the artificial portion is created over a removable form. From two large bottles of the liquid monomer and powdered polymer, a small amount of each is placed into two individual glass containers, so as not to contaminate the larger bottles. Also, the smaller amounts of these substances are more workable. These small containers usually hold approximately 30 mL and can be open to the air. Another type of container commonly used for the monomer has a small opening for an application brush to enter when pressure is applied by the technician. The nail is formed entirely by this small brush applicator, which is dipped into the liquid monomer, then dipped into the powdered polymer. The polymer contains a peroxide accelerator. The nail technician then forms the nail into the general shape before curing (hardening) fully takes place.

- Preformed tips are preferred if the client has a sufficient nail length to which the tip can be attached. This technique involves the use of preformed artificial nail tips that are attached over the natural nail with an ethyl cyanoacrylate glue and then shaped. The tips are made of acrylics, fiberglass, or porcelain. The tip is then covered with a liquid monomer and powdered polymer, using the same procedure used to form sculptured nails.

After the artificial nails are formed, the nail is filed to the desired shape either manually using a nail file, or by using a small mechanical file with a special tip. Cuticle oil is applied over the nail surface and cuticle, and the nail is buffed. A base coat of primer is applied, followed by a color coat, and topped with a clear protective coat. The initial application of the nails takes generally 1 to 2 hours. As the natural nails underneath the artificial portion grow, there is a gap near the cuticle where the nails must be filled in with the acrylic. These "fill-ins" take from 30 minutes to 1 hour. These "fill-ins" are applied about every 2 weeks. The procedure for fill-ins is the same as the initial application, except there is no need for the removable form. Exposures result from off-gassing of organic solvents, methacrylate monomers, and dust generated when the artificial or natural nails are filed.

The products used at the cosmetology school where the present study was performed were NSI nail products (Nail Systems International, West Conshohocken, Pa.). Both the NSI liquid and powder are composed primarily of ethyl methacrylate. There were trace concentrations of methyl methacrylate detected in both the liquid and powder. The NSI primer was mainly composed of methacrylic acid and contained trace amounts of methyl methacrylate. The dehydrating liquid (NSI NailPure) was mainly composed of methyl ethyl ketone. The trace amounts of the methyl methacrylate in the products are most likely impurities in the ethyl methacrylate or the methacrylic acid, not an added component of the product.

METHODS

Preliminary Data Gathering

To become more familiar with the general procedure for artificial nail application and the possible contaminants, several walk-through surveys were conducted before the in-depth study was conducted. In the Denver area, three nail salons and a cosmetology school were visited. The process of artificial nail application was observed, and any local exhaust ventilation systems at the various sites were also examined. At the first salon visited, there were downdraft ventilation manicure tables with charcoal filters in use; these were constructed by the owners of the salon. The downdraft ventilation on these tables was turned on only when the technician was filing the nails (natural and/or polymer). The nail technicians commented that during the actual artificial nail application, the product crystallized too quickly when the downdraft table fan was used due to increased airflow past the nails. The accelerated and uneven crystallization (curing of the polymer) reduced the time the technician had to form the product to the proper shape. For this reason most of the procedure was performed without the use of the downdraft ventilation. However, during the in-depth testing later performed by NIOSH researchers at the cosmetology school, the technicians stated that they did not notice accelerated curing when using the modified ventilated table.

During one of the preliminary walk-through surveys, limited air sampling was conducted using a hand-held aerosol monitor (HAM), a direct-reading instrument that sampled for particulates; sorbent tubes were used to sample for ethyl and methyl methacrylates. The levels of dust were very near the detection limit of the HAM, and the sorbent tube results indicated levels at or below the limit of detection for ethyl and methyl methacrylate.

Commercially Available Manicure Table

To lower exposures in nail salons, various controls were examined. The best control option appeared to be a downdraft manicure

table. A commercially available recirculating downdraft manicure table with a charcoal filter was purchased and evaluated (model #0592M, Professional Fabricators, Inc., Cypress, Calif.) (Figure 1). However, several manufacturers have similar designs. The table was 1.0 m (3.4 ft) long by 0.5 m (1.5 ft) wide and 0.8 m (2.6 ft) high. On the client's side of the table, a 13.2 cm (5.2 in.) wide padded arm rest was extended from the table. The client's side of the table was 6.6 cm (2.6 in.) higher than the technician's working surface, so the client's hands would extend over the downdraft face of the table, approximately 6 in. from the surface. The downdraft air exhausted through a perforated plate located 16.5 cm (6.5 in.) from the technician's side of the table. The perforated plate was 33.0 cm (13 in.) long and 10.7 cm (4.2 in.) wide, with 67.3% void space. A small centrifugal fan was used to create the downdraft flow. The measured average flow of downdraft air through the table as purchased was 0.03 m³/sec (62 ft³/min); the average face velocity was measured at 0.8 m/sec (160 ft/min). The hands of the client during application would be approximately 6 in. from the surface of the table; the velocity at this distance was 0.15 m/sec (30 ft/min). The air passed through a carbon filter and exited the table through the bottom.

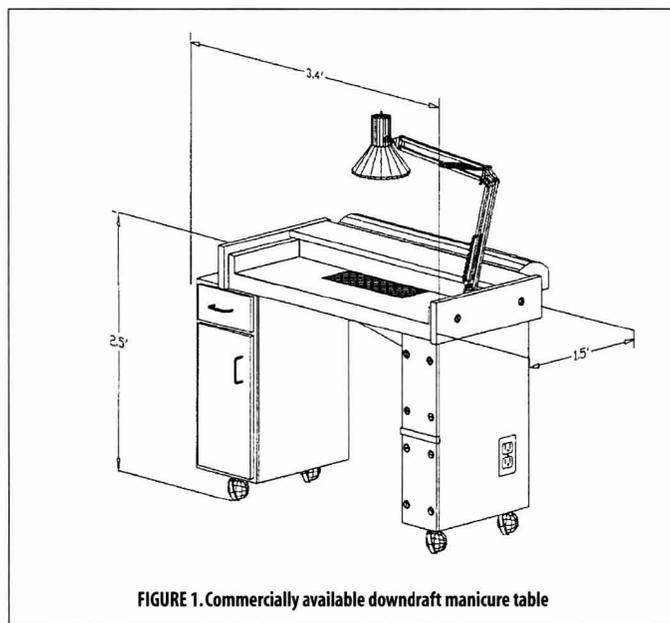


FIGURE 1. Commercially available downdraft manicure table

The ventilation of the manicure table was deemed inadequate due to the following factors: (1) leaks detected around the charcoal filter allowed potentially contaminated air to escape before reaching the filter; (2) there was no indicator to warn the operator when the filter needed replacing, nor was there a backup filter as recommended by good ventilation practice;⁽¹⁴⁾ (3) airflow across the face of the downdraft opening was uneven; and (4) the velocity of air was not adequate to capture contaminants at a level of 6 in. from the table surface, where the application would take place.

NIOSH researchers made the following modifications to the commercially available manicure table: (1) the downdraft air volume was increased from 0.03 m³/sec to 0.11 m³/sec (62 to 235 ft³/min) by using a larger fan; (2) the plenum was enlarged such that the plenum velocity equaled half the perforated plate velocity for more consistent airflow rates across the face of the table, as is suggested by good ventilation practice;⁽¹⁵⁾ (3) the charcoal filters were removed and an exhaust system was installed; and (4) an extension was added around the duct leading to the perforated plate at the face of the table. The extension brought the duct

(downdraft plenum) on the technician's side up approximately 6.6 cm (2.6 in.), to the height of the client's side of the table. This modified downdraft manicure table is shown in Figure 2.

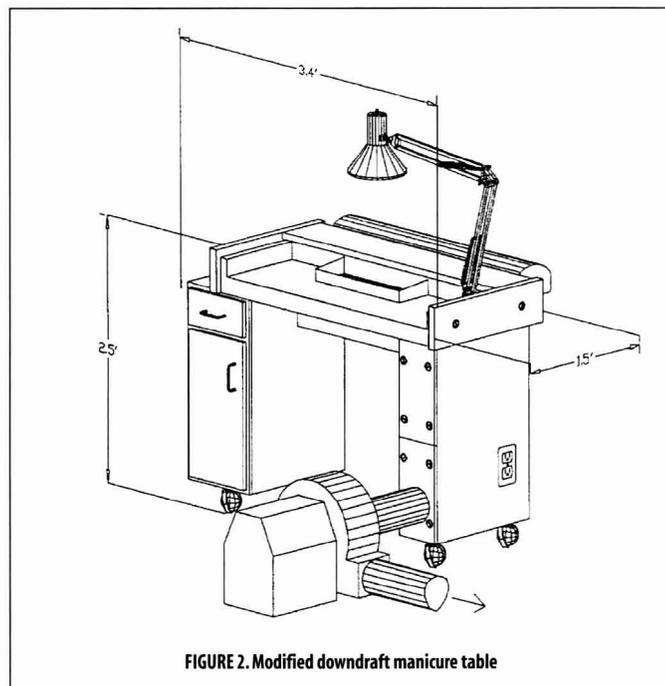


FIGURE 2. Modified downdraft manicure table

The table was installed in a Cincinnati school of cosmetology and evaluated during actual artificial nail application. An outdoor exhaust system was installed, using approximately 8 ft of flexible corrugated duct with a diameter of 4 in. The duct connected the downdraft exhaust from the manicure table to an opening in an outside wall that was previously an exhaust for the building.

Air Sampling Strategy

The evaluation was performed using the modified manicure table with downdraft ventilation with two configurations: the ventilation was turned off to represent a common unventilated table and was turned on to represent a ventilated table.

There were 3 full days of sampling for each of the two configurations; the order of the configurations was random. Four different technicians applied nails, using the same product throughout the testing period. The technicians applied from two to four nail sets per day.

Air sampling for methyl and ethyl methacrylate was performed according to NIOSH Method 2537.⁽¹⁶⁾ The samples were collected with XAD-2 solid sorbent tubes (#226-30-06, SKC, Inc., Eighty Four, Pa.) using Gilian[®] (Gilian Instrument Corp., W. Caldwell, N.J.) air sampling pumps. After sampling, the sorbent tubes were stored on dry ice until analysis. Air samples were collected in the technician's personal breathing zone (PBZ) at a flow rate of 0.05 L/min for each set of nails. Air samples were also collected for the entire school day (around 6 hours) at a flow rate of 0.02 L/min at three locations: (1) in the technician's PBZ; (2) on the manicure table, approximately 0.5 m (1.5 ft) from the technician; and (3) in the salon extended area, approximately 3.0 m (10 ft) from the technician.

Relative concentrations of organic compounds were examined using a Photovac MicroTIP[™] (Photovac Inc., Thornhill, Ontario, Canada). This instrument detected the total ionizable solvents present in volts (the term "ionizable" means gases that can be photoionized by a miniature lamp inside the instrument). The output of

the MicroTIP (in volts) was recorded using a Rustrak Ranger™ data logger (Gulton Industries, Inc., E. Greenwich, R.I.). These data were collected to qualitatively analyze how work practices were related to worker exposures. The MicroTIP was located approximately 1 ft from the technician. Before work began on each set of nails, the MicroTIP was calibrated with 100 ppm isobutylene to measure for relative amounts of organics.

TABLE I. Ethyl Methacrylate Sample Results

Configuration	Sample Area	n Samples	Geometric Mean(ppm)	Geometric Standard Deviation
Unventilated ^A	personal—1 set of nails	10	8.7	2.0
Ventilated ^B	personal—1 set of nails	8	0.6	2.3
Unventilated	personal—day (TWA)	3	9.4	1.4
Ventilated	personal—day (TWA)	3	0.7	2.0
Unventilated	table	3	1.7	1.2
Ventilated	table	3	0.4	1.1
Unventilated	extended area	3	0.4	1.5
Ventilated	extended area	3	0.3	1.1

^ACommercially available unventilated manicure table

^BModified commercially available ventilated manicure table

RESULTS

Methyl methacrylate concentrations were nondetectable for all the sorbent tube samples taken during the in-depth study. This was expected, since there were only trace amounts of methyl methacrylate in the bulk artificial nail application products. The ethyl methacrylate data were lognormally distributed. All ethyl methacrylate data are shown in the in-depth survey report.⁽⁴⁾

For purposes of statistical analysis, the ethyl methacrylate sample results that were reported as ND (nondetectable) were calculated to be at the limit of detection (LOD). This results in obtaining the most conservative estimate of the ND value. The LOD reported in the laboratory results was 0.01 mg/sample of ethyl or methyl methacrylate. If the value was between the LOD and limit of quantitation (LOQ), the reported value was used. The LOQ reported in the laboratory results was 0.033 mg/sample of ethyl or methyl methacrylate.

When all the samples taken during the application of one nail set were pooled and examined, it was found that there was no statistical difference among the four technicians who applied nails during the survey ($p=0.1219$). There was also no statistical difference between the days that nails were applied ($p=0.2379$). Therefore, neither the technician nor the day was considered to be a variable.

Ethyl methacrylate PBZ samples were compared when using the modified vented table versus the unvented table. The results indicated that for the individual nail sets, as well as those collected over the entire school day, exposures were statistically different as a function of table configuration, $p=0.0001$ and $p=0.0045$, respectively. A comparison of the ethyl methacrylate area sample results located on the manicure table that were taken for the entire day indicated that exposures were also statistically different as a function of table configuration ($p=0.0001$). These values indicated there was less exposure to ethyl methacrylate during application with the modified ventilated table versus the unventilated table. However, in the extended area, a comparison of the ethyl methacrylate results taken for the entire school day indicated that exposures were not statistically different as a function of table configuration ($p=0.2959$).

As shown in Table I, when the unventilated table was used, the PBZ ethyl methacrylate geometric mean was 8.7 ppm per set of artificial nails; the modified ventilated table had a geometric mean of 0.6 ppm per set of nails. The PBZ sample results showed an ethyl methacrylate geometric mean of 9.4 ppm during the entire day of applying artificial nails with the unventilated table; the modified ventilated table had a geometric mean of 0.7 ppm. The application time in this study ranged from approximately 1 hour to almost 3 hours. The table area and extended area sample results are also shown in Table I.

As expected, because the chemicals used were organic, the highest readings from the Photovac MicroTIP were at the beginning of the application of the nail set—during the removal of nail polish, sanitization, and the actual application of the artificial nail product. Readings were also high near the end of the process, during the application of the color coat (color polish). For sanitation reasons between clients, the nail technician used a square piece of gauze to soak up the remaining nail liquid monomer (primarily ethyl methacrylate) stored in the small open glass container, approximately 30 mL. It was then discarded in a covered trash can beside the manicure table. Elevated readings occurred as the monomer was absorbed by the gauze and whenever the trash can was opened.

DISCUSSION

Personal exposures to ethyl methacrylate during artificial nail application were reduced more than tenfold when use of the modified ventilated manicure table was compared to the unventilated manicure table. The concentrations observed in the present study indicate that ethyl methacrylate exposures can be controlled to 0.7 ppm on a time-weighted average with the modified ventilated table, as compared with a range of 7 to 14 ppm with the unventilated table. The exposures to methyl methacrylate measured during this study and others⁽¹¹⁻¹³⁾ were well below the current NIOSH recommended exposure level (REL) and Occupational Safety and Health Administration (OSHA) permissible exposure level (PEL) of 100 ppm as an 8-hour time-weighted average.

With the exception of the general area samples collected in the extended area, all sampling results indicate that the modified ventilated manicure table was better at lowering exposures to ethyl methacrylates than was the unventilated table. The extended area sample results were lower for the modified ventilated table, although not statistically significant, than for the unventilated table. Since the exposures in the extended area were detectable, the results show that people in surrounding areas are also potentially exposed to ethyl methacrylate and other chemicals. The surrounding area exposures could be significant when several technicians apply nails concurrently.

In previous walk-through evaluations at other salons, nail technicians commented that when they used the tables with downdraft ventilation, the additional airflow caused the nail product to crystallize too quickly during application. However, the technicians at the cosmetology school during this study did not believe that the additional ventilation caused the nail application products to evaporate more quickly or the nails to dry faster. This difference in opinion could be due to product or application technique

variations between the different facilities. The technicians also believed the vented table used for this study reduced the dust levels.

Exposures are reduced because of the location of the local exhaust ventilation system with respect to the source of exposure and the location of the technician's PBZ. Good ventilation techniques included the distribution of the capture potential evenly over the perforated plate near the client's hands and a downdraft design that moved the vapors away from the technician and client's PBZ. In addition, the modified ventilated table was versatile and practical for the needs of most manicure processes. The technicians told the researchers that both the customers and the technicians themselves preferred the ventilated table when compared to an unventilated table, primarily due to the major reduction of odor.

Other observations revealed that airborne contaminant concentrations could be lowered further by modifying work practices, including (1) having the technicians place the gauze pad soaked in the ethyl methacrylate solution in a sealed bag before placing it in the trash can (can liners should be changed daily); (2) having the technician try not to pour out an excess of the nail liquid into the container from which they work; and (3) using containers with only a small opening for an application brush to enter when pressure is applied, not a container open to the air. Such containers would result in less evaporation of the product, thereby reducing potential exposures to methacrylates.

Nail technicians generally do not use any personal protective equipment. As the artificial nails are removed, chips of acrylic often become airborne, creating a need for eye protection. Technicians should be provided with personal protective equipment, such as gloves, safety glasses, and dust masks as appropriate. Technicians should wash their hands and other exposed areas with mild soap and water several times throughout the day to remove potentially irritating dust; long-sleeved garments should be worn to help to avoid this dust. At many salons, nail technicians and clients often drink and eat at the manicure table. Eating or drinking should not be permitted in the work areas, since unintentional contact with methacrylates on the face can cause dermatitis.⁽⁵⁾ Also, there are many other chemicals located in a salon that if ingested can cause health problems. The manicure area during this study also served as a smoking area. Smoking should be eliminated from the entire salon because many chemicals in a salon, including nail products, are very flammable.

CONCLUSION

Exposures observed in this and other studies indicate that methyl methacrylate concentrations are below OSHA PELs and NIOSH RELs. There are no corresponding regulations or standards for ethyl methacrylate; however, there is evidence that it is toxicologically similar to methyl methacrylate.⁽⁸⁾ Although the exposures to methacrylates are relatively low, it appears that some technicians are adversely affected by the chemical exposures associated with artificial nail application. It is suggested that salons use a downdraft manicure table with a downdraft exhaust volume of 235 ft³/min, such as the one studied in this article. If salon owners wish to construct their own manicure table using the general modified ventilated table design, there are many considerations. The downdraft table ventilation design should be quiet so as not to interfere with client comfort or conversation. Also, the system should have a properly maintained dust filter to prevent dust build-up in the ducts. Makeup air must be provided to account for the air exhausted. An inadequate volume of makeup air results in negative pressure areas, perhaps resulting in drafts. However, adequate

makeup air is often provided naturally through outside entries, windows, etc. If makeup air is introduced, it should enter the room a distance from the exhaust so that short-circuiting is not a concern.

Implementation of these recommendations should help nail salons achieve the goal of maintaining exposures to ethyl methacrylate and other volatile organic chemicals as low as is technically feasible. Effective engineering measures, good work practices, and appropriate personal protective equipment should be implemented and maintained to keep exposures to the lowest feasible concentrations.

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