

Environmental Hazards within Nail Salons

by

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May 2011

Masters project submitted in partial fulfillment of the
requirements for the Master of Environmental Management degree in
the Nicholas School of the Environment of
Duke University

2011

Abstract

In the United States there are over 80,000 registered synthetic chemicals; 9,000-15,000 of which are currently in use. Nail salons are a hotbed of chemical activity with salon workers coming in contact with over 20 chemicals each day. Three main chemicals have recently come under fire for being hazardous to manicurists' health. Named the "toxic trio," toluene, dibutyl phthalate, and formaldehyde have been thoroughly investigated by many organizations and found to be hazardous. Unfortunately, there are a host of other chemicals found in nail salons that have not been studied as carefully or received as much attention as the "toxic trio." My client, *Women's Voices for the Earth*, was interested in learning about any potential hazardous health effects of methyl methacrylate, methyl ethyl ketone, and acetone. I was tasked with conducting a synthesis and quantitative analysis of the available literature to determine whether or not methyl methacrylate, methyl ethyl ketone and acetone were comparable to toluene, dibutyl phthalate, and formaldehyde in toxicity. I used major online databases including Pubmed (Ovid MEDLINE) and Toxicology Literature Online (TOXLINE) to locate peer-reviewed journals. I used 94 papers, an average of 16 per chemical then grouped each study based on whether the conclusions supported the null or alternate hypothesis. Finally, I ran a one-tailed binomial test to eliminate Type 1 Error. Methyl ethyl ketone was found to be less harmful than methyl methacrylate and acetone was determined to be one of the least harmful substances present in nail salons. Methyl methacrylate and the toxic trio should be prioritized over methyl ethyl ketone and acetone when advocating for manicurists' health.

Introduction

There are currently over 80,000 synthetic, man-made chemicals registered with the US Environmental Protection Agency (EPA, Substance Registry Service). In Europe there are over 100,000 registered chemicals according to the European Inventory of Existing Commercial Substances (EINECS) of which, 60,000 are currently in use (McElhatton 2003). Of the US's 80,000 registered substances, 9,000-15,000 are currently in use. Approximately 3,000 of those actively used chemicals are categorized as "high production volume" (Goldman 2000). High production volume means that each one of those 3,000 chemicals are produced or imported into the US at quantities greater than 1 million pounds each year (Sorensen 2009). And since most of those chemicals are produced or imported in quantities greater than 1 million pounds, some estimates put the total amount of synthetic substances being released into our environment at over 7 trillion pounds per year (Sorensen 2009).

Furthermore, the vast majority of these actively produced chemicals have not been tested for safety (Sorensen 2009). The Food and Drug Administration (FDA) permits many harmful chemicals including known carcinogens and reproductive toxins to enter the marketplace under the "Trade Secret" loophole. For example, this loophole allows manufacturers to hide ingredients in "fragrances" in cosmetics from the consumer. A fragrance is usually a cocktail of, on average, 14 different substances and is a component of most cosmetic products including shampoos, lotions, perfumes, makeup and nail care products (Sarantis et al. 2010). In 1973 the Federal Fair Packaging and Labeling Act required cosmetic manufacturers to list all the ingredients on the product label but exempt them from listing what goes into their "fragrances" (Sarantis et al. 2010). Furthermore, the FDA does not have the authority to evaluate chemical ingredients for potential hazardous health effects.

Therefore, it is important for independent organizations and scientists to conduct their own investigations of potential environmental hazards. One of many NGOs interested in examining how toxic chemicals affect human health, women's health in particular, is *Women's Voices for the Earth* (WVE). I contacted WVE to see if I could help with any of their ongoing investigations. They requested I examine some of the chemicals present in nail salons.

Nail salons utilize large quantities of chemicals. Salon workers come in contact with over 20 regularly used chemicals each day. The number of nail salons in the United States is growing at a rapid pace and each year the industry earns over \$6 billion (NAILS Magazine 2007). Three main chemicals have recently come under fire for being hazardous to worker health. Named the "toxic trio," toluene, phthalates, and formaldehyde have been thoroughly investigated by many organizations (including WVE) and found to be hazardous to manicurists' health (Scranton 2007).

Unfortunately there are a host of other chemicals found in nail salons that have not been studied as carefully or received as much attention as the "toxic trio." WVE was interested in learning about any potential hazardous health effects of methyl methacrylate (MMA), methyl ethyl ketone (MEK), and acetone. I was tasked with conducting a review, synthesis and analysis of the available literature to determine whether or not MMA, MEK and acetone were comparable to toluene, DBP and formaldehyde in toxicity. Based on the data, I could then identify whether or not those substances could be harmful to salon employees.

The Employees

According to industry statistics, 96% of salon workers are women and 60% are non-white (NAILS Magazine 2007). Nearly half of all nail salon technicians in the United States are Vietnamese, a group that has traditionally worked in nail salons. Manicurist is an accessible

profession for newly immigrated populations. It does not require an extensive grasp of the English language or an advanced degree. Despite the fact that nearly half of all manicurists in the United States are immigrants from Vietnam; Material Safety Data Sheets are not widely available in Vietnamese (Porter 2009). This puts workers at a disadvantage where their health and safety are concerned.

Discount salons can rarely afford the costly ventilations systems that come highly recommended when working with the chemicals manicurists commonly use (NICNAS 2009). The two pathways these specific chemicals enter the worker's bloodstream are inhalation and absorption through the skin. As such, most salon workers wear face masks and gloves while performing services for their clients. Unfortunately, the majority of face masks worn in salons are meant to shield against particulates from filing nails and fail to keep out contaminated air (Maxfield 1997).

Methods

This study involved a comprehensive literature review of peer-reviewed journals. I used two major, well-known and respected online databases including Pubmed (Ovid MEDLINE) and Toxicology Literature Online (TOXLINE). The Duke Library reference staff showed me where to find TOXLINE and how to use it effectively. These databases focused on environmental and occupational health as well as articles on medicine and health science. As of November 2010, MEDLINE is home to over 5,511 different journals and over 20 million citations (www.nlm.nih.gov). I found relevant papers in 56 different journals. I used the journals available in these databases to understand whether or not MEM, MEK, acetone, toluene, DBP and formaldehyde had harmful effects on human health. Because I wanted to establish a case for

each chemical, it was important to review the entire history of testing to understand how the research community understands to be the danger of each chemical. For this reason, I chose not to limit my search to only the most recent papers. I found that once a chemical is largely considered to produce certain health effects, they are no longer tested in the same ways for the same health effects each year.

Aside from peer-reviewed articles from medical journals, I also reviewed peer-reviewed articles from journals focusing on women's studies, sociology, psychology, and environmental science. I also examined OSHA and NIOSH specifications as well as Material Safety Data Sheets, popular magazine sources, industry publications, FDA and EPA recommendations and blogs. These I limited to more recent articles (less than 10 years old) because they centered on current laws and regulations as well as up-to-date industry standards and practices.

When searching peer-reviewed journals I was careful to use keywords and phrases that would produce papers documenting both negative and benign health effects for each chemical of my six substances. These phrases included:

- *chemical* health effects
- *chemical* hazardous + health effects
- *chemical* safety
- *chemical* occupational exposure
- *chemical* environmental + occupational exposure
- *chemical* salon worker + manicurist
- Salon worker + manicurist + occupational hazard
- Salon worker +manicurist safety

Next, I searched for specific symptoms. Using the five most common side effects found in my preliminary search, I paired each chemical with each of the most common side effect:

- Contact dermatitis → MEM, MEK, Acetone, Toluene, DBP, Formaldehyde
- Eye, nose, throat, lung irritant → MEM, MEK, Acetone, Toluene, DBP, Formaldehyde
- Neurotoxin → MEM, MEK, Acetone, Toluene, DBP, Formaldehyde
- Carcinogenic → MEM, MEK, Acetone, Toluene, DBP, Formaldehyde
- Reproductive toxin → MEM, MEK, Acetone, Toluene, DBP, Formaldehyde

Looking at peer-reviewed journals alone, I read 131 articles. When I expanded my search to include the nail industry, environmental NGOs, the FDA, the EPA, blogs and OSHA recommendations, I was able to locate numerous useful and credible sources about manicurists and nail salons. Given the extensiveness and detail of the search and subject matter, the real challenge was organizing and synthesizing the information into a cohesive, understandable report.

After reviewing all the material, I chose to separate the *Results* section into two large subdivisions. The first will be the results from the meta-analysis and the second will give an overview of what the literature has to say about the potential hazardous health effects of each of the six chemicals. I broke the health effects into the five major categories I previously mentioned (skin irritation, eye, nose, throat and lung irritation, carcinogen, neurotoxin and developmental toxin). Another subdivision focuses specifically on manicurists and environmental occupational safety within nail salons. The purpose of this organization is to demonstrate the health effects in laboratory and industrial settings (where a majority of these experiments occurred) and then show how they manifest themselves in nail salon workers, specifically.

Meta-analysis

The purpose of this study was to explore the strength of the relationship between each of the chemicals and their effect on human health. As such, I needed to measure the strength of the relationship between the two variables, or the effect size. For example, to what extent does MMA exposure harm your health? In order to produce quantitative results from a narrative review I conducted a meta-analysis of the primary literature (peer-reviewed papers). Defined as “the statistical analysis of a large collection of analysis results for the purpose of integrating the findings,” a meta-analysis is basically a quantitative synthesis that applies the same “methodological rigor” of experimental research to a narrative review (Glass 1976 DeCoster 2004). Also categorized as an “analysis of analyses,” meta-analyses help draw conclusions from existing data (Gieles 1999).

Upon completion of my literature review, I performed a quantitative analysis of all the peer-reviewed papers. My null hypothesis was; exposure to MMA, MEK, or acetone does not cause harmful health effects. I coded three aspects of each paper. First I grouped each peer-reviewed study into one of my six chemical groups; MMA, MEK, acetone, toluene, DBP, or formaldehyde. Next, I classified each paper based on whether the conclusions supported, rejected or were ambivalent (that is, the author determined the results of the study to be inconclusive) to my hypothesis. Thirdly, I coded and tabulated each symptom that resulted from the papers that rejected my null hypothesis.

The final steps of the meta-analysis were to determine the relationship between each of the chemicals and their potential to exact harmful health effects, determine the most common symptoms (if any) caused by each chemical, and compare their toxicity to the toxic trio. This included a one-tailed binomial test to eliminate Type 1 Error, or false positives.

Results

Quantitative Analysis

I found 94 papers and grouped each study into one of my six relevant chemical groups. Based on their conclusions, each paper was then classified as supporting, rejecting or ambivalent to my hypothesis. Below is a table showing the number of papers used in each chemical group. Each group averaged 15.67 studies.

MMA	23
MEK	15
Acetone	6
Toluene	19
DBP	17
Formaldehyde	14
	94 total

The bar graphs give a visual representation of the number of findings within each group. For MMA, the majority of the papers reject the null hypothesis. There are more papers supporting the null hypothesis in both MEK and acetone. The large majority of the papers for each member of the toxic trio show them to produce harmful health effects, supporting earlier assertions that they are indeed occupational hazards. I evaluated toluene, DBP, and formaldehyde in a similar manner because my second objective was to compare the toxicity of my three assigned chemicals (MMA, MEK, and acetone) to the toxic trio (toluene, DBP, and formaldehyde).

Methyl Methacrylate

Of the 23 papers examining methyl methacrylate, 18 papers supported the alternate hypothesis, 3 supported the null hypothesis and 2 were inconclusive. After conducting a one-tailed binomial test comparing the number of papers in support of the alternate hypothesis to the number of papers in support of the null hypothesis, I found the a p -value $< 2.2e-16$.

Next, I looked at the 18 papers that supported the alternate hypothesis. I charted the frequency each symptom (skin, eye, nose, lung, brain, reproductive, cancer) occurred. I took the percentage of each symptom's occurrence. For example, skin irritation manifested in 39.13% of the all the studies in support of the alternate hypothesis while eye irritation only occurred 4.35% of the time. 13.04% reported nose irritation, 30.43% reported lung problems, 4.35% observed neurological effects, 4.35% reproductive effects and 4.35% reported instances of cancer.

Methyl Ethyl Ketone

Of the 15 papers examining the health effects of MEK, 3 were in support of the alternate hypothesis while 8 were in support of the null hypothesis and 4 were unsure. I conducted a binomial analysis comparing the number of papers in support of the alternate hypothesis to the number of papers in support of the null hypothesis and found a p -value = 0.0362.

Looking at the symptom distribution, 20% of all the papers in support of the alternate hypothesis resulted in skin irritation and 40% of the time papers reported lung irritation in the form of occupational asthma. 20% reported neurological effects, 20% reported reproductive problems and there were no instances of cancer, eye and nose irritation.

Acetone

The 6 papers I found on acetone, none were in support of the alternate hypothesis while 5 were in support of the null hypothesis and 1 was unsure. Running the binomial test again, it was

no surprise to get a p -value of 1 (p -value = 1) since there were zero papers in support of the alternate hypothesis. Because there were no papers in the support of the alternate hypothesis, zero papers reported symptoms from exposure.

Toluene

For the 19 papers on toluene, 15 were in support of the alternate hypothesis, 2 were in support of the null hypothesis and 2 were inconclusive. I ended up with a small p -value (p -value < 2.2e-16). Looking at the symptom distribution, the only hazardous health effect from toluene is teratogenic (reproductive). 100% of all papers reported hazardous health effects cited problems with reproductive health as the only symptom. No other side effects were reported.

DBP

For the 17 papers on DBP, 13 were in support of the alternate hypothesis, 1 was in support of the null hypothesis and 3 were unsure. With a p -value of 2.402e-14, we can be sure the reason behind why so many papers cite DBP as causing hazardous health effects is not because of Type 1 Error. As for the specific symptoms, 87.5% of the time papers reported problems with reproductive health and 12.5% of the time papers reported instances of cancer.

Formaldehyde

Of the 14 papers on formaldehyde, 12 were in support of the alternate hypothesis, 1 was in support of the null hypothesis and 1 was unsure. With a p -value of 2.021e-14, we can be sure the reason behind why so many papers cite formaldehyde as causing hazardous health effects is not due to Type 1 Error. Taking a closer look at the specific symptoms, we see that 10% of the time, paper report instances of skin irritation. 20% of the papers included nose irritation while 70% of the papers reported instances of cancer.

Discussion

Methyl Methacrylate and Nail Salons

Methyl methacrylate (MMA) is used in adhesives, sealants, bone cement, vinyl siding, and dentures. It is also widely used in the cosmetics industry, specifically in nail salons in applying artificial acrylic nails. The National Institute for Occupational Safety and Health described the acrylic nail application processes as;

“The unreacted liquid methacrylate monomer is mixed with a methacrylate polymer powder at the time of application, and painted onto the nails. A cross-linking chemical reaction occurs between the monomer and the polymer mix, and the mixture hardens very quickly. The resultant nail can be filed, ground, and polished (NICNAS 2009).”

MMA was once a common material in acrylic nail application but due to the increased awareness of the hazardous health effects, ethyl methacrylate (EMA) is commonly substituted for MMA (NICNAS 2009). In the 1970, the Food and Drug Administration (FDA) attempted to ban the use of nail products made entirely of MMA. The FDA looked to manufacturers to stop making products containing MMA. The FDA, in 2005, reiterated that stance on the use of MMA calling it a “poisonous and deleterious substance,” and as a result, over half the states banned the use of MMA in nail salons (US FDA 2005, NICNAS 2009). North Carolina is one of those states (Bonn 2001).

Despite the bans, many salons continue using MMA because it is much cheaper than the EMA substitute. For example, one gallon of EMA liquid monomer costs between \$189.00-219.00 while the same amount of MMA costs between \$9.00-22.00 (www.beautyweb.com). And according to industry statistics, the majority of salon owners spend less than \$150 each month on total supply purchases (NAILS 2007). Therefore, it would be naïve to assume salon

workers and clients are not being exposed to MMA just because there is a ban in place. For these reasons, my client requested an in-depth literature review on the hazardous health effects as well as recommendations on whether it is possible to restrict their usage.

Methyl Methacrylate

MMA has been shown to cause contact dermatitis, which is skin irritation and inflammation. The Cosmetic Ingredient Review Expert Panel, a board of independent researchers founded by the Personal Care Products Council and the FDA, in 2005, in their own literature review, found methacrylate esters to cause dermal irritation on rabbits and guinea pigs. According to their research, MMA is safe to use on nails but should never come in contact with the surrounding skin. MMA nail primers are very acidic and can cause severe burns to the skin (Woolf 1999). However, given the nature of acrylic nail application, it is very difficult to contain the chemical to the hard nail surface alone. The Concise International Chemical Assessment Document confirmed the findings of the Expert Panel and stated that MMA is irritating to human skin and can result in skin sensitization to clients who are especially allergic. Kanerva et al. (1996) detailed a case study that established a woman's dermatitis of the hands was a direct result of methacrylates found in her nail care product. In 2008 the Cosmetic Ingredient Review Board recommended technicians be trained on how to use methacrylic acid safely so as to avoid any and all contact with the skin.

Aside from being a skin irritant, MMA proved to be a nose, throat and lung irritant. After exposing rats and rabbits to MMA through inhalation, scientists found 16-20% of the substance was metabolized in the upper respiratory tract and resulted in eye and nasal cavity irritation (Concise International Chemical Assessment 1998). After two years of inhaling methacrylate at a concentration of 410 mg/m³ lab rats showed deterioration of the olfactory epithelium. This

particular study determined the no observable effect level (NOEL) to be at 100 mg/m³ (Concise International Chemical Assessment 1998). A different study exposed a group of rats to MMA under poor and normal ventilation and observed “degeneration of olfactory epithelium, bronchopneumonia...hemorrhage, emphysema and epithelial hyperplasia” which were absent in the control group breathing normal air (Aydin 2002).

Dentists and dental hygienists are also exposed to methacrylates which are used as bonding agents in fillings and manufacturing dentures. Hagberg et al. (2005) found that dental personnel who were repeatedly exposed to methacrylates were at risk of developing respiratory diseases. Daily exposure of methacrylates was notably linked to adult-onset asthma, coughing and other respiratory problems (Jaakkola 2007). Dental workers’ lung and nasal symptoms increased significantly with daily use of methacrylates, strongly suggesting a serious occupational hazard (Jaakkola 2007).

All the literature agreed that MMA was non-carcinogenic. The Cosmetic Ingredient Review found no evidence of endocrine disrupting capabilities or carcinogenic effects at any level of dosage. Data on how MMA affects the brain and nervous system was mainly limited to industrial settings. Absorbed through the skin, MMA can influence and even impair workers’ abilities to perform (Rajaniemi 1989). One study found that rats after orally ingesting 500 mg/kg of MMA for 21 days showed locomotor impairment and changes in the biochemistry of the brain (Concise International Chemical Assessment 1998).

One study on this subject came from LoSasso’s 2002 report on the neuropsychological effects of solvents and methacrylates on nail salon technicians. The author found that salon workers performed worse in neurological tests than the controls. More interestingly, the study concluded that the type of neurosensory changes observed in the nail salon workers were

comparable to similar changes observed in workers exposed to the same chemicals in different professions.

Finally, studies on the teratogenic effects of MMA were more limited. Teratogenic is the potential to harm the growth and development of the embryo or fetus but the studies mainly focused on maternal health or how the chemical affected reproductive organs. One study showed no reduction in fertility or harm to the reproductive organs of rats even at the lethal dose of 36,900 mg/m³ (Concise International Chemical Assessment 1998). The Cosmetic Ingredient Review Board in 2008 agreed that methacrylic acid was not harmful to reproduction and further stated that there were no teratogenic effects.

Methyl Ethyl Ketone

Methyl ethyl ketone is found in nail polish and nail polish and acrylic nail remover. I analyzed the literature for any health effects methyl ethyl ketone might have on humans and similarly classified the effects into different categories. The two more common hazardous health effects were problems with fertility and reproduction and neurological damage (Sallmen 2008, Ukai 2010).

The only report to investigate whether or not methyl ethyl ketone (MEK) causes skin irritation could not trace the hand lesions back to MEK (Klemme 1985). O'Donoghue found MEK to be non-carcinogenic and unlikely to be toxic to mammalian genes. One of the larger concerns about MEK is whether not it is harmful to pregnant women. One recent literature review by McElhatton (2003) found that repeated exposure to MEK, and organic solvents in general, put women at risk of having miscarriages. Another investigation at a shoe factory that used organic solvents and MEK discovered a reduction in fertility and concluded that MEK, among other chemicals, was hazardous to women's reproductive health (Sallmen 2008).

In regards to eye, nose, throat and lung irritation, the best comprehensive report was from NIOSH in the *Information Profiles on Potential Occupational Hazards*. It stated that, when taken by mouth or inhalation, MEK causes hyperemia of the lungs (congestion) and hemorrhage in lab rats. Employees who worked with methyl ethyl ketone complained of respiratory problems (Karches 1972). The rest of the literature focused on neurological effects of MEK.

One study of male workers who were exposed to a variety of chemicals including MEK complained of depression and irritation. The author's concluded the symptoms were not attributed to MEK but rather toluene (Ukai 2010). MEK was found to be most toxic when associated or used in addition to, n-hexane. Hexane is a hydrocarbon present in nail salons (Report of Industrial Hygiene for Isabella Nail Bar, 2010). One study by Takeuchi (1983) suggests MEK use be avoided when working with n-hexane. A second study supported Takeuchi's findings and concluded that MEK by itself was not a neurotoxin but when it was used in conjunction with n-hexane, the chemicals produced hazardous conditions to human health (Altenkirch 1978). Drug addicts who abuse MEK showed slower response times (Geller 1979). However, another, more recent, study found no significant changes in performance (Dick 1989).

Acetone

Acetone is used as a nail polish remover and acrylic nail remover. Acetone is largely considered to be one of the least toxic solvents. Some studies showed acetone to be irritating to the nose, eyes and throat as well as the skin but only with chronic exposure. It also has the potential to affect the central nervous system.

Because of its instability, acetone affects the mucous membranes of the nose, eyes and throat (Matsushita 1960). Another study looked at the health effects of acetone in factory workers and found the employees mainly suffered from eye and nose irritation (Sato 1996).

The Material Safety Data Sheet (MSDS) for acetone stated “vapors are irritating to the eyes” and could seriously injure the lungs. With chronic exposure to the skin one might expect to feel dry, cracked skin, or contact dermatitis.

As far as neurological effects, some employees who were exposed to acetone claimed to feel nausea and faintness (Satoh 1996). The same study recommended the current exposure limit (750 ppm) be lowered in order to guard against hazardous health effects. The MSDS warned inhalation might result in dizziness, headache and depression of the central nervous system.

Aside from minor eye, nose, throat and skin irritation and slight neurological effects, acetone is non-carcinogenic. It has also been tested in vitro and showed no signs of developmental toxicity. The Canadian Center for Occupational Health and Safety asserts there is “no strong evidence of chronic health effects if basic precautions are followed.” Overall, acetone is a largely benign solvent. In 1995 the EPA delisted acetone from the list of “toxic chemicals” under section 313 of EPCRA (Emergency Planning and Community Right to Know Act).

Toluene

Toluene is a volatile solvent found in nail polish. It keeps the pigment (color) equally distributed throughout the polish and leaves a smooth finish after painting and is also present in nail glues. When the polish dries, toluene evaporates into the air (Gorman 2007). While not shown to be carcinogenic (HESIS 2005), toluene is an eye, nose and throat irritant and has been shown to have teratogenic and neurotoxic effects. As a result, numerous manufacturers have removed toluene from their product.

At 100 ppm, toluene was irritating to the eyes and nose with continued exposure leading to dizziness and headache (Andersen 1983). Toluene will irritate the lungs, cause shortness of

breath and at extreme levels of exposure result in pulmonary edema (fluid-filled lungs) (HESIS 2005).

A number of studies outline the teratogenic (developmental) effects of toluene exposure. Tests on animals linked toluene with developmental and skeletal retardation, reduced birth weight and premature delivery. Similar effects were observed in women who abused toluene through inhalation during pregnancy (Donald 1991). Hersh (1988) found abnormalities in the head and limbs, attention deficit disorder, and developmental deficiency present in children whose mothers intentionally inhaled toluene. In laboratory rats, exposure to toluene resulted in severe retardation of development of the fetus (Hudak 1978). Another study found a positive correlation “between spontaneous abortion and exposure to organic solvents during pregnancy” (Lindbohm 1990).

As for neurological effects, toluene has been proven to impact the central nervous system (Hersh 1988) and cause depression, headaches and dizziness (Parkinson 1990). Toluene can also affect workers’ hearing. Employees exposed to toluene were more likely to experience hearing loss than those not exposed to toluene. Toluene interferes with the “central auditory pathway” and is a clear occupational hazard (Morata 1993).

DBP

Dibutyl phthalate (DBP) is a plasticizing agent found in a wide variety of cosmetic and personal care products. Within nail salons DBP is often found in nail polishes giving nails “flexibility and a moisturizing sheen (Scranton 2009).” DBP can be absorbed through the skin or through inhalation. Phthalates are likely a developmental or reproductive toxin and have been shown to affect sperm count and penis development in male mice (Houlihan and Wiles 2000). Officially, environmental laws in the United States recognize phthalates as toxic materials.

Paradoxically, if an organization releases 10 pounds of phthalates into the environment under the Superfund law they have to report it to the authorities. But the cosmetic industry is allowed to put hundreds of thousands of pounds of DBP in nail polish each year with no requirements, no safety inspection, testing or reporting (Houlihan and Wiles 2000).

The main health hazard associated with DBP is the potential to act as a reproductive toxin. After exposing male rats to DBP, scientists observed “malformations in the male reproductive tract, and histological testicular lesions (Barlow 2004).” These findings supported a previous study by the National Toxicology Program’s Center for the Evaluation of Risks to Human Reproduction that found DBP reduced sperm counts and interfered with penis development (CERHR 2000). Another study found DBP to be weakly estrogenic which is believed to be a contributing factor in breast and testicular cancer (Jobling 1995).

Phthalates are persistent in the environment and accumulate in the body. Recent studies have revealed they are even present in human breast milk. Pellizzari et al. (1982) examined breast milk to possible link environmental pollution with human health effects. The authors found numerous other chemicals besides insecticide and pesticide residue. They discovered the presence of volatile organic pollutants, methyl ethyl ketone and DBP. More recent studies support the fact that humans are vectors for pollution and are now producing milk contaminated by synthetic chemicals. For example, scientists found chlorinated dioxins and PCBs and connected higher levels of pollutants in breast milk and proximity to industrial areas (Schechter 1989). Another study published last year continued to find phthalates, UV filters and pesticides in human breast milk (Schlump 2010).

Formaldehyde

Formaldehyde is used in industrial settings as a resin and preservative and can be found in nail polishes for the purpose of providing a smooth finishing coat and nail hardeners (Gorman 2007). Formaldehyde is also present in household products, paper products, plywood, and disinfectants (OSHA 2002). Formaldehyde can cause skin, eye, nose, throat and lung irritation and is a known carcinogen. In animal studies, 10 ppm proved to be carcinogenic in rats (McLaughlin 1994).

The Occupational Safety and Health Administration (OSHA) fact sheet outlines the hazardous health effects of formaldehyde. OSHA states that ingesting formaldehyde can result in death while exposure to the skin can cause contact dermatitis. This is supported by another study that found sufferers of contact dermatitis were overwhelmingly (75%) using products that contained formaldehyde (Lundov 2010). The chemical can also irritate the eyes and respiratory tract resulting in asthma. Breathing concentrations as low as 0.1 ppm can result in lung and throat irritation while concentrations of 100 ppm can be fatal (OSHA 2002). Wheezing and coughing can also develop over time (Gorman 2007).

OSHA suspects formaldehyde causes lung and nasal cancer in humans (2002). Past studies which examine the possible link between formaldehyde and cancer contain numerous confounding factors in industrial settings or were conducted exclusively on lab animals. One study exposed sets of 120 male rats and 120 female rats to formaldehyde gas at concentrations ranging from 0 to 14.3 ppm 6 hours a day, five days a week for 24 months. They found a significant number of formaldehyde-induced lesions in the nasal cavity and trachea. Furthermore, the highest concentrations of formaldehyde resulted in the greatest number of lesions. And while rhinitis, epithelial dysplasia and squamous metaplasia appeared in all groups

exposed to formaldehyde, rats exposed to the highest concentration (14.3 ppm) developed cancerous cells in 103 cases (52 females and 51 males) (Kerns 1983).

Other studies looked at the use of formaldehyde in industrial settings. Workers in most situations were exposed to other substances as well, making it difficult to tease apart the effects of formaldehyde alone. Olsen et al. (1984) discovered a statistically significant link between nasal cancer and occupational formaldehyde exposure but believed the presence of wood dust in addition to formaldehyde produced an additive effect, increasing cancer risk. One study in France examined the frequency of nasal cancer in occupations that use formaldehyde. The authors did not find a significant positive association between exposure to formaldehyde and nasal cancer but did state that confounding exposure to wood dust may increase the risk of nasal cancer (Luce 1993). This lends support to an earlier study which also looked at formaldehyde exposure and workers' risk of cancer. The authors looked at over 26,000 workers but failed to connect formaldehyde exposure alone to significant rates of cancer. Again, there were numerous other substances present in the work environment that acted as confounders. The authors concluded that the use of phenol and wood dust, in addition to formaldehyde, should be further examined (Blair 1990). Overall, formaldehyde is shown to produce cancerous cells in lab studies on rats but is difficult to prove carcinogenic in industrial settings on humans where it is impossible to control for numerous other factors that may influence workers' health (McLaughlin 1994).

The Manicurists, Qualitative Studies

Many of the studies I've referenced were carried out in a lab on test animals or in an industrial setting like shoe or carpet factories. There have also been several important studies

examining the occupational safety hazards of working in an actual salon. The main topics of concern were reproductive health, cancer, dermatitis and asthma. Many of the studies gathered information through surveys and relied on direct feedback from employees. These papers serve as invaluable glimpses into salon working environments.

Given that the salon industry is dominated by professional women, reproductive health has emerged as an important area of concern for many workers. One author surveyed 8,356 salon workers between the ages of 22-36 who became pregnant between 1983 and 1988. 74% of the women responded, and the author found an association between spontaneous abortions and “the number of hours worked per day, the number of chemical services performed per week, the use of formaldehyde-based disinfectants, and work in salons where nail sculpturing was performed (Esther 1994).” The author failed to find a significant association but stated this study justified further investigation into the health of salon workers. Another study compared the birth weight, premature delivery, SGA (small for gestation age), and perinatal death of hairdressers and cosmetologists to a control group (teachers). They found the risks of SGA and perinatal death was higher in cosmetologists when compared to the control group. This study adds to the mounting evidence that working in salons adds a reproductive risk (Halliday-Bell et al. 2009). A contradictory study found no connection between low birth weights and cosmetologists (Herd-Losavio 2010).

Endocrine disruptors and their potential connection to cancer have received a lot of attention in recent years. Two studies looked at the risk of cancer specifically within nail salons. One alternative to sculptured acrylic nails are gel nails. But gel nails come with another risk. Gel nails are cured under a UV light, similar to tanning beds. One study found two cases of women developing non-melanoma skin cancers. These women had no family history of cancer and both

reported using UV nail lights to cure gel nails. This is a very limited study with no significant, concrete association but it does warrant further study (MacFarlane et al. 2009). Quach et al. (2010) performed a comprehensive study on manicurists and instances of cancer. The author looked at cancer occurring in the general population compared to occurrences of cancer in licensed manicurists in California between 1988- 2005. Overall, in 325,225 licensed manicurists, 9,044 reported cases of cancer. Proportionally, this showed working as a manicurist does not increase your risk of cancer but given the limitations of licensee files and the given age cohort, which might be too young to show signs of cancer, the authors believe further study is needed to come to conclusive results (Quach et al. 2010).

Dermatitis is also a risk for manicurists. Ectopic dermatitis (distant contact allergy) is common in applying nail hardeners, nail polish, gel acrylic nails and sculptured acrylic nails (Baran 2002). Adverse effects on the skin are a common side effect of nail products (Heymann 2007). It is a pervasive problem in the industry. One survey reported as many as 1/3 of manicurists experience dermatitis and irritation (Roelofs et al. 2007).

There is also the chronic problem of occupational asthma associated with working in a nail salon. Manicurists work bent over patrons' hands 1-2 feet away from the sculpting process; a process that involves breathing in chemical vapors and particulate matter from applying and filing down acrylic nails (Brown 1987). It is also important to remember that this process is repeated throughout the day, several days a week. And while wearing a face mask is encouraged, not all employees do. Even face masks are limited in their ability to reduce chronic exposure. Chronic, occupational respiratory problems specific to manicurists have been reported in several studies. In one survey, manicurists reported suffering from lung irritation, dust and bad-smelling products (Roelofs et al. 2007). Another study found that applying and sculpting

artificial nails was significantly linked with occupational asthma (developing asthma as a direct result of employment) (Kreiss et al. 2006). A third study looked at lung function in relation to occupation. Manicurists experienced more trouble breathing than did the controls. And while the findings were not statistically significant, they did show a relationship (Reutman 2009).

In summary, not only did an analysis of the chemicals themselves produce the aforementioned symptoms (reproductive problems, cancer, and skin and lung irritation) but they were shown to have identical effects on manicurists when taken out of the lab or industrial setting and applied to real-world salons.

Limitations

There are some important limitations with a literature review. As I previously alluded to, some of the background information on substances taken from MEDLINE and TOXNET were much older than the more recent studies I was able to find on manicurists and occupational hazards within nail salons. However, this does not make those studies invalid; it only adds to the body of evidence on a certain chemical. Furthermore, articles on my substances of interest as dating as recently as 2010 referenced previous studies dating back to the 1970s to support their ideas.

Another factor to consider is the dearth of testing being done on women and workers outside of industrial settings. We understand that men and women metabolize synthetic chemicals in their bodies differently. Women tend to bioaccumulate synthetic chemicals more readily than men and subsequently pass on these higher concentrations of synthetic substances to their children through breast milk (Schlumpf 2010).

Yet another consideration would be keeping in mind where the testing is taking place. Europe, does not permit as high levels of chemical exposure in the workplace as does America.

And many of the most recent occupational studies I reference take place in Europe. Higher occupational exposure standards as well as increased follow-up testing and enforcement might suggest different attitudes toward environmental limits in Europe than in America.

Conclusion

For my client, Women's Voices for the Earth, I conducted an extensive literature review and synthesis about any potential hazardous health effects of methyl methacrylate (MMA), methyl ethyl ketone (MEK), and acetone. I compared my analysis of those three chemicals with the "toxic trio", toluene, DBP and formaldehyde.

MMA

The literature review proved MMA to be an occupational health hazard after chronic exposure. In the short-term, it is extremely irritating to the skin, resulting in contact dermatitis and it is recommended that manicurists wear gloves at all times. Aside from damaging skin and resulting in contact allergies, MMA is also very irritating to the nose, throat and lungs. Chronic exposure can lead to occupational asthma or other respiratory problems. Similar health effects were felt by workers exposed to MMA across occupations and even in industrial settings. Dental hygienists who work with MMA showed sign of occupational asthma, similar to manicurists. It also has the potential to impair locomotor movement and affect the nervous system. No studies showed MMA to have carcinogenic or teratogenic effects.

Looking at the final bar graph; of the 23 papers examining MMA, 18 came to the conclusion that MMA is harmful to human health, only 3 said MMA is not harmful and 2 were inconclusive. A vast majority of the papers on MMA were in support of the alternate hypothesis. Furthermore, after conducting a binomial analysis comparing the number of papers in support of

the alternate hypothesis to the number of papers in support of the null hypothesis, I found an extremely small p -value (p -value $< 2.2e-16$). This means that it is highly unlikely that the papers are present because of Type 1 Error, or “false positive.” This means that something else is going on besides Type 1 Error that is causing the papers to be distributed in such a way.

Examining the frequency and distribution of the types of symptoms caused by MMA exposure; we see a wide range of harmful side-effects. The two main health effects were contact dermatitis (skin irritation) and lung problems in the form of occupational asthma. But some studies also found MMA to be responsible for eye and nose irritation as well as having the ability to produce neurological, reproductive and carcinogenic side-effects.

MEK

MEK was found to be less harmful than MMA but still potentially dangerous. MEK tended to produce teratogenic effects as well as respiratory problems but was found to be most harmful when used in conjunction with n-hexane. Of the 15 papers used in this study, only 3 were in support of the alternate hypothesis while 8 were in support of the null hypothesis and 4 were unsure. I conducted a binomial analysis comparing the number of papers in the alternate and null categories. I found a p -value (p -value = 0.0362) that was much larger than MMA but still under 0.05.

Looking at the symptom distribution, there were no instances where MEK was an eye or nose irritant. It also proved to be non-carcinogenic. The main symptoms that resulted from MEK exposure were asthma, neurological and reproductive effects.

MEK might therefore be a chemical of greater concern for women wishing to have children. It is important for manicurists to understand the risks of MEK given that, according to industry statistics, 96% of salon workers are female (NAILS 2007). Not only are the

overwhelming majority of salons workers female, 94% of the clients are female as well (NAILS 2007).

Acetone

Acetone is one of the least harmful chemicals present in nail salons. Workers mostly suffer from eye and nose irritation and contact dermatitis after long-term exposure and not wearing gloves. Acetone is not carcinogenic nor does it have teratogenic effects. After long periods of inhalation, one might expect to experience dizziness, headache and depression of the central nervous system. MMA, MEK and the toxic trio should be prioritized over acetone.

Of the 6 papers I found on acetone, none were in support of the alternate hypothesis while 5 were in support of the null hypothesis and 1 was unsure. Running the binomial test again, it was no surprise to get a p -value of 1 (p -value = 1). Looking at the symptoms, according to the papers, the only effect acetone has on human health is eye irritation. No other symptoms were found in any of the papers.

Toxic Trio

In order to compare MMA, MEK and acetone to the toxic trio, I had to conduct the same meta-analysis for each of those chemicals in order to understand which chemicals should be prioritized. Looking at my data, it is clear toluene, DBP, and formaldehyde are widely considered bad for your health by the literature. Of the 19 papers on toluene, 15 were in support of the alternate hypothesis, only 2 were in support of the null hypothesis and 2 were inconclusive. I ended up with a very small p -value (p -value < 2.2e-16) which proves Type 1 Error is not responsible for unfairly staking papers in the wrong category. Looking at the symptom distribution, the only hazardous health effect from toluene is teratogenic

(reproductive). No other side effects were reported. The stories are similar for DBP and formaldehyde.

Of the 17 papers on DBP, 13 were in support of the alternate hypothesis, only 1 was in support of the null hypothesis and 3 were unsure. With a p -value of $2.402e-14$, we can be sure the reason behind why so many papers cite DBP as causing hazardous health effects is not because of Type 1 Error. As for the specific symptoms, there were 7 instances where papers found DBP to cause reproductive harm and one instance of cancer.

Of the 14 papers on formaldehyde, 12 were in support of the alternate hypothesis, only 1 was in support of the null hypothesis and 1 was unsure. With a very small p -value of $2.021e-14$, we can be sure the reason behind why so many papers cite formaldehyde as causing hazardous health effects is not due to Type 1 Error. Taking a closer look at the specific symptoms, we see formaldehyde most often result in instances of cancer. To a lesser extent, formaldehyde can also cause skin and nose irritation.

Prioritization of Chemicals of Concern

How do these three newly examined chemicals (MMA, MEK and acetone) compare to the more popularized “toxic trio” or toluene, DBP and formaldehyde? My results show that a majority of the scientific community agrees that MMA is in fact harmful to human health. I believe MMA should be receiving as much attention as toluene, DBP, and formaldehyde. MMA should be made a priority on the same level as the toxic trio. Despite its ban in 30 states, it is still prevalent in discount salons and needs to be accounted for.

My results for MEK and acetone on the other hand, showed them to be less harmful to human health both compared to MMA and the toxic trio. MEK has a few studies showing them to be harmful to human health but they were not the majority. MEK commonly failed to produce

harmful health effects on its own but its toxicity could be amplified by other substances. MEK was most harmful when paired with other chemicals such as n-hexane or wood-dust. Neither of which are usually found in nail salons. Therefore, MEK should be not a priority when considering chemicals of concern in nail salons. Policy makers and advocates should focus on the dangers of MMA and the toxic trio.

Similarly, acetone failed to show substantial harmful health effects in humans. My search failed to produce a single study that supported my alternate hypothesis. Material Safety Data Sheets warn against eye irritation over long periods of exposure but lab studies failed to find any long-term harmful health effects associated with extended periods of acetone use. Acetone is largely considered the safest, most innocuous solvent used in industry today. Taking all this into account, I would not prioritize acetone over MMA or any members of the toxic trio. Acetone should be last on the list of chemicals of concern within nail salons.

Criticisms of Meta-analyses

Like all forms of analysis, quantitative literature reviews are subject to criticisms. One criticism is that meta-analyses are an overgeneralization of the findings (DeCoster 2004). While it is important to recognize that this type of analysis does look at a large number of research papers, it is also important to remember that this analysis was not an over-simplification. Each paper was recognized in the tabulation and had an influence over the synthesis. A second criticism is that this type of review is a “garbage-in, garbage-out” process which is described as poor-quality data producing poor-quality results (DeCoster 2004). I would argue the methods for the retrieval of papers are outlined in the *Methods* section and they are high-quality papers with good data. A third criticism is the misconception that the performer of the analysis is ignoring the quality of the papers being included (DeCoster 2004). I did not include any study whose

methods I found to be dubious. A final criticism is that this type of analysis is susceptible to subjectivity (DeCoster 2004). I would argue all experiments are subject to some sort of bias, intended or unintended, but that it is important to be transparent and open to outside examination. I have listed all the studies I used and how they were coded and classified.

Figures

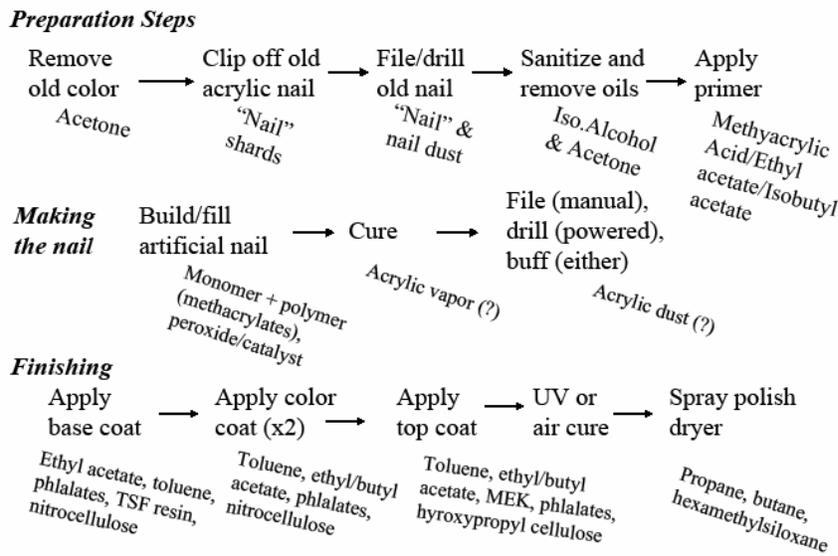


Figure 1. Sculptured Nail Process Diagram. Roelofs 2007.

Chemical	Occupational Exposure Limits
Acetone	250 ppm
Methyl methacrylate	100 ppm
Methyl Ethyl Ketone	200 ppm
Toluene	100 ppm
DBP	0.43 ppm
Formaldehyde	0.1 ppm

Table 1. Occupational exposure limits from NIOSH pocket guide to chemical hazards.

	Methyl methacrylate	
Alternate	Null	Unsure
Cosmetic Ingredient Review Expert Panel, 2007	Almaguer et al., 1997	Reutman et al., 2009
Hagberg et al., 2005	Rajaniemi et al., 1989	Tsigonia et al., 2010
Marquardt et al., 2008	Heath et al., 2009	
Kanerva et al., 1996		
Sauni et al., 2008		
LoSasso et al., 2002		
Woolf et al., 1999		
Aydin, O., 2002		
Chan et al., 1988		
Haughton et al., 2008		
Jaakkola et al., 2007		
Moore et al., 1988		
Toren et al., 2007		
Dearfield et al., 1989		
Dormer et al., 1998		
Singh et al., 2010		
Piirila et al., 1998		
Baran, R. 2002		

Table 2. List of each paper used in the meta-analysis of methyl methacrylate.

	Methyl ethyl ketone	
Alternate	Null	Unsure
Van Engelen et al., 1997	Decker, D., 1983	Klemme, J. 1985
Sallmen et al., 2008	O'Donoghue et al., 1988	McElhatton, P. 2003
Anonymous, CDC, NIOSH	Ukai et al., 2010	Karches et al., 1972
	Takeuchi et al., 1983	Dick et al., 1989
	Geller et al., 1979	
	Dick et al., 1984	
	Altenkirch, H. 1978	
	Chang et al., 2003	

Table 3. List of each paper used in the meta-analysis of methyl ethyl ketone.

	Acetone	
Alternate	Null	Unsure
	Satoh et al., 1996	Kawai et al., 1992
	Wigaeus et al., 1984	
	Matsushita et al., 1969	
	OSHA	
	EPA	

Table 4. List of each paper used in the meta-analysis of acetone.

	Toluene	
Alternate	Null	Unsure
Andersen et al., 1983	Ng et al., 1992	Nomiyama et al., 1973
Donald et al., 1991	Shigeta et al., 1986	Parkinson et al., 1990
Hersh, J. 1988		
Hudak et al., 1978		
Lindbohm et al., 1990		
Luderer et al., 1999		
Morata et al., 1993		
McDonald et al., 1987		
Anonymous, CPEIS		
Porter, C et al. 2009		
Anonymous, New Ecology		
Houlihan, J. et al., 2000		
Scranton, A. 2009		
Silberberger et al., 2009		
Gorman, A. 2007		

Table 5. List of each paper used in the meta-analysis of toluene.

	Dibutyl phthalate	
Alternate	Null	Unsure
Anonymous, CPEIS	Rogan, W. 1996	Jobling, S. 1995
Porter, C et al. 2009		Autain, J. 1973
Anonymous, New Ecology		Schechter et al., 1989
Houlihan, J. et al., 2000		
Scranton, A. 2009		
Barlow, et al. 2004		
Anonymous, CERHR		
Kwapniewski et al., 2008		
Blount et al., 2000		
Pellizzari et al., 1982		
Schlumpf et al., 2010		
Roelofs, C. 2007		
Gorman, A. 2007		

Table 6. List of each paper used in the meta-analysis of DBP.

	Formaldehyde	
Alternate	Null	Unsure
Lundov et al., 2010	Blair et al., 1990	McLaughlin et al., 1994
OSHA		
Kerns et al., 1983		
Olsen et al., 1985		
Luce et al., 1993		
Roelofs, C. 2007		
Gorman, A. 2007		
Porter, C et al. 2009		
Anonymous, New Ecology		
Houlihan, J. et al., 2000		
Scranton, A. 2009		
Silberberger et al., 2009		

Table 7. List of each paper used in the meta-analysis of formaldehyde.

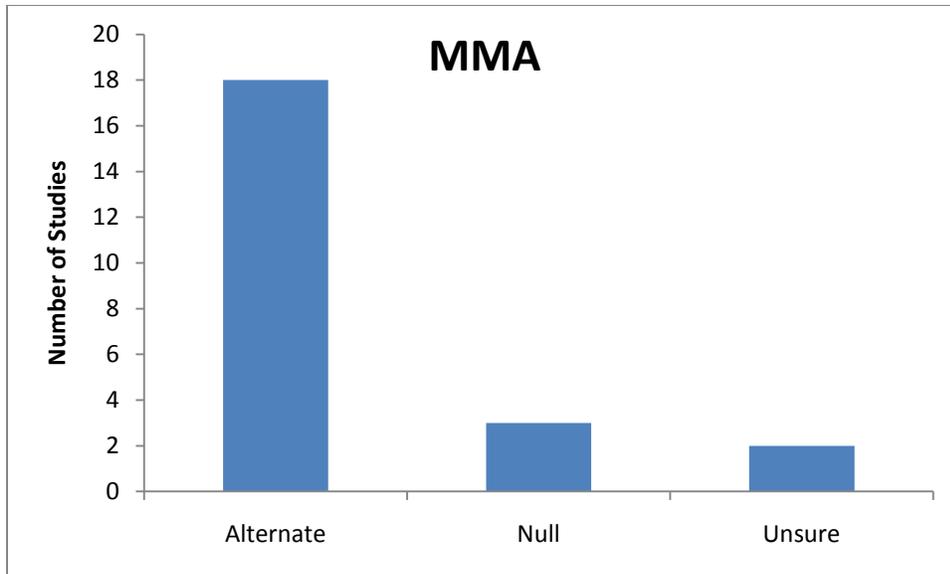


Figure 2. Number of studies in support of either the alternate or null hypothesis or unsure for methyl methacrylate.

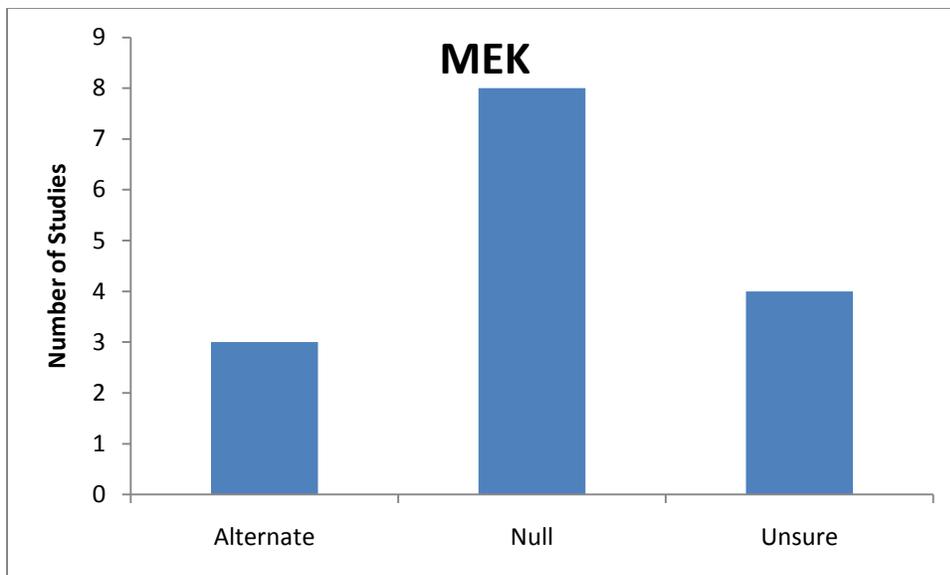


Figure 3. Number of studies in support of either the alternate or null hypothesis or unsure for methyl ethyl ketone.

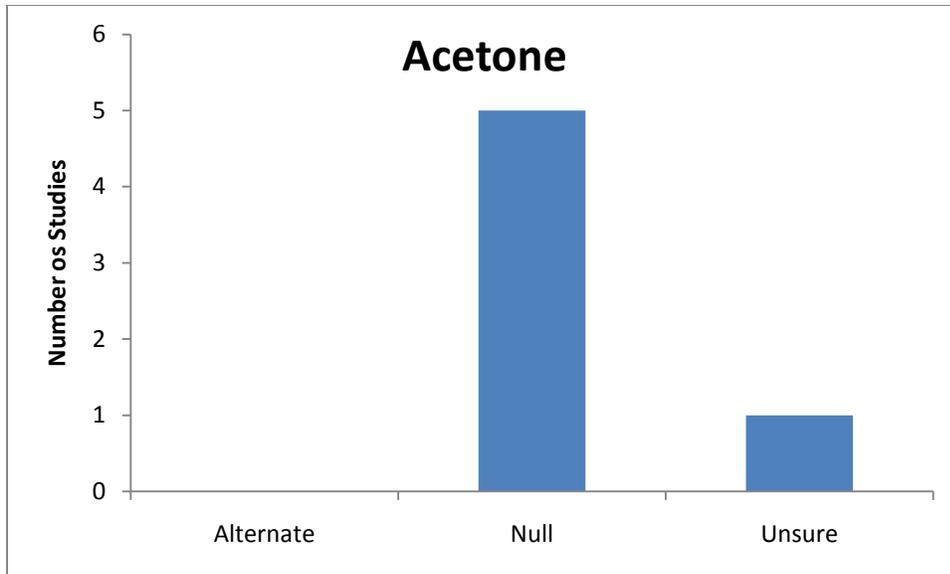


Figure 4. Number of studies in support of either the alternate or null hypothesis or unsure for acetone.

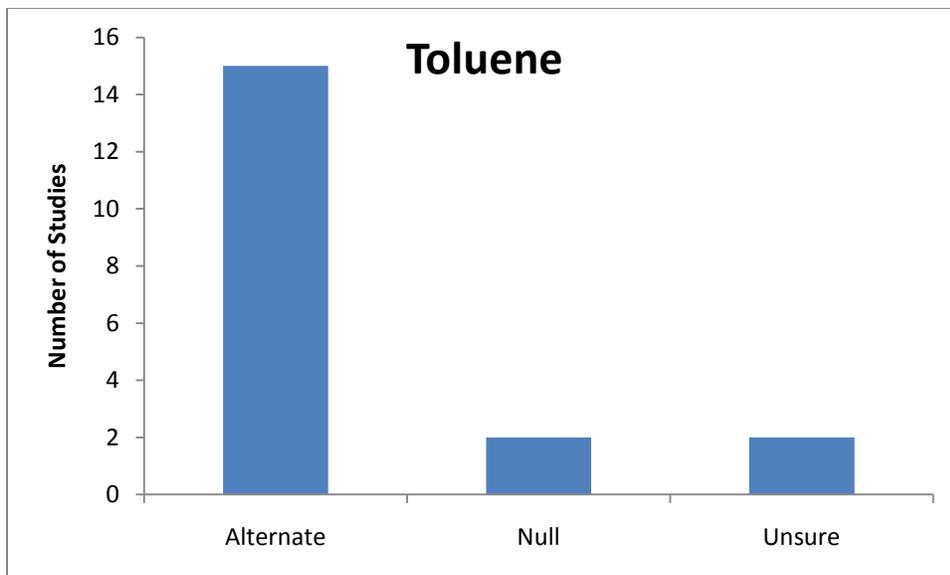


Figure 5. Number of studies in support of either the alternate or null hypothesis or unsure for toluene.

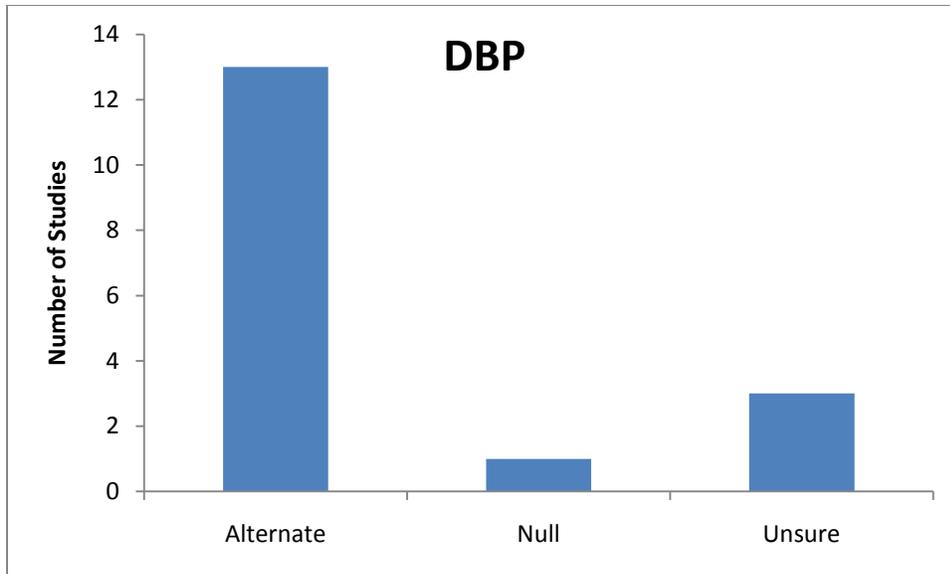


Figure 6. Number of studies in support of either the alternate or null hypothesis or unsure for dibutyl phthalate.

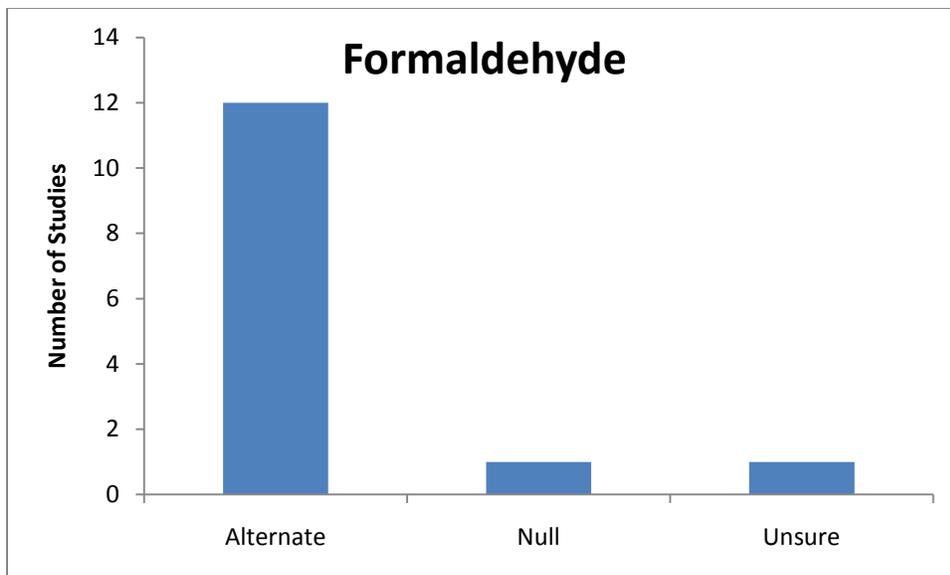


Figure 7. Number of studies in support of either the alternate or null hypothesis or unsure for formaldehyde.

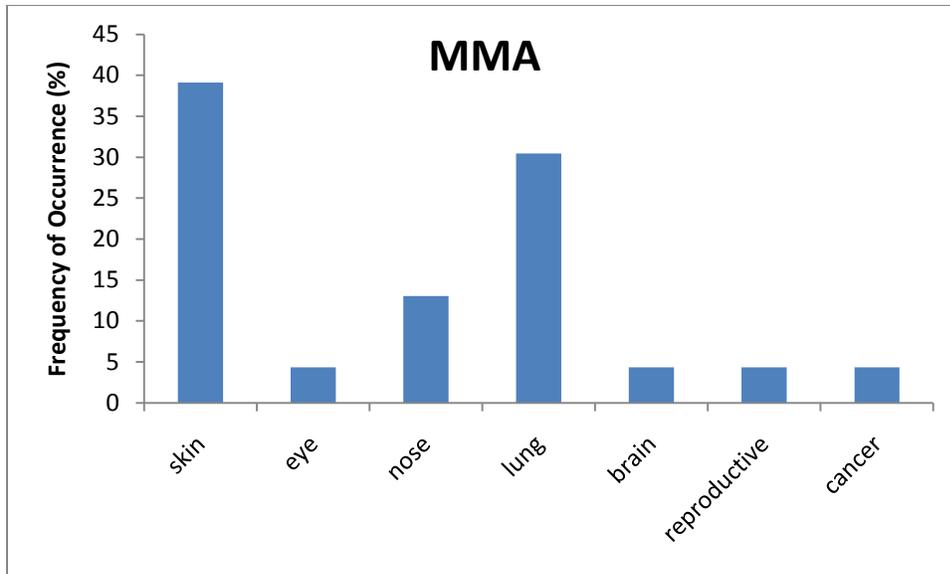


Figure 8. Frequency distribution of side-effects from exposure to MMA.

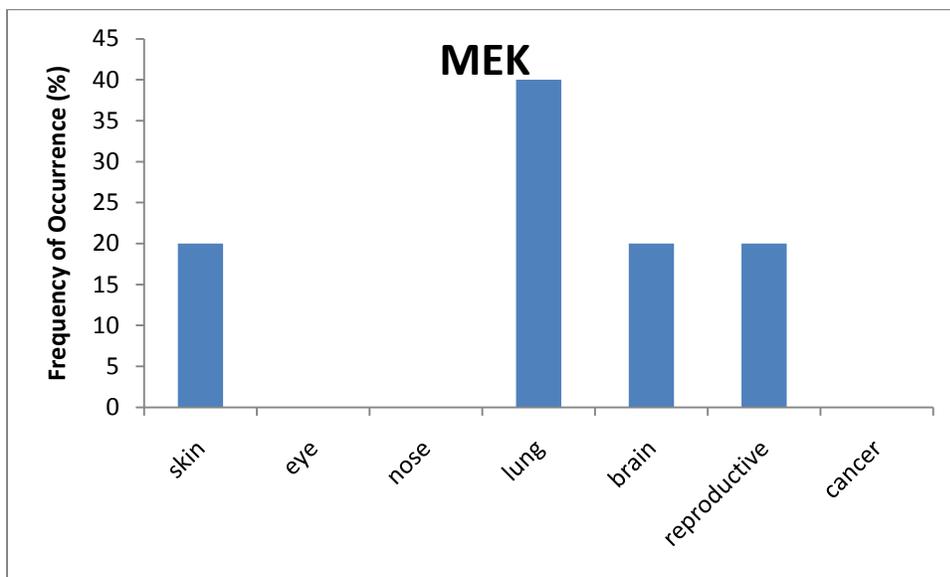


Figure 9. Frequency distribution of side-effect from exposure to MEK.

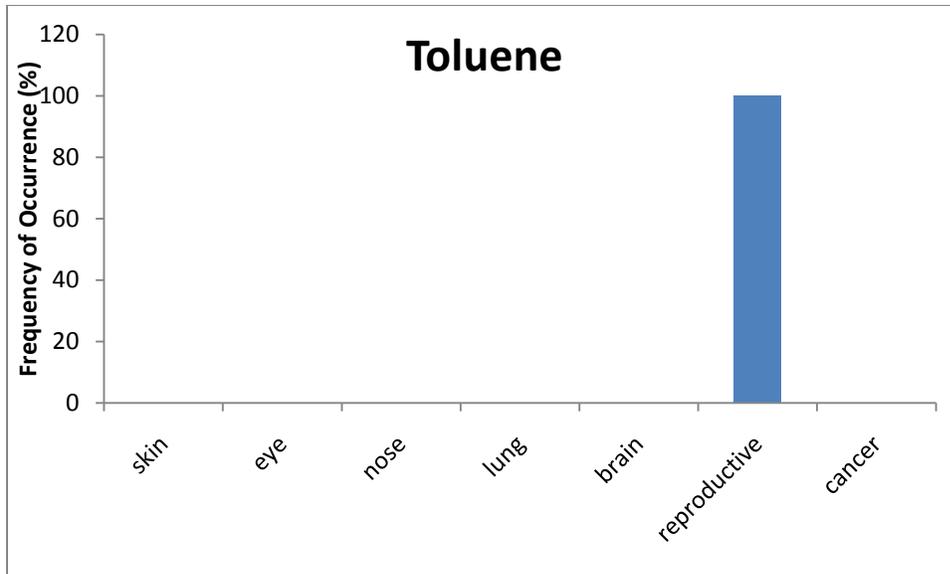


Figure 10. Frequency distribution of side-effects from exposure to toluene.

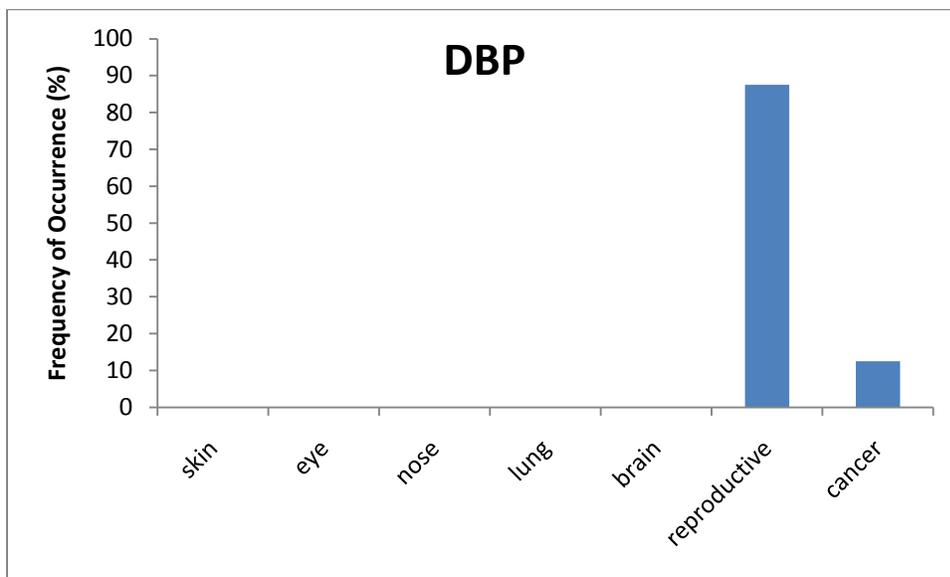


Figure 11. Frequency distribution of side-effects from exposure to DBP.

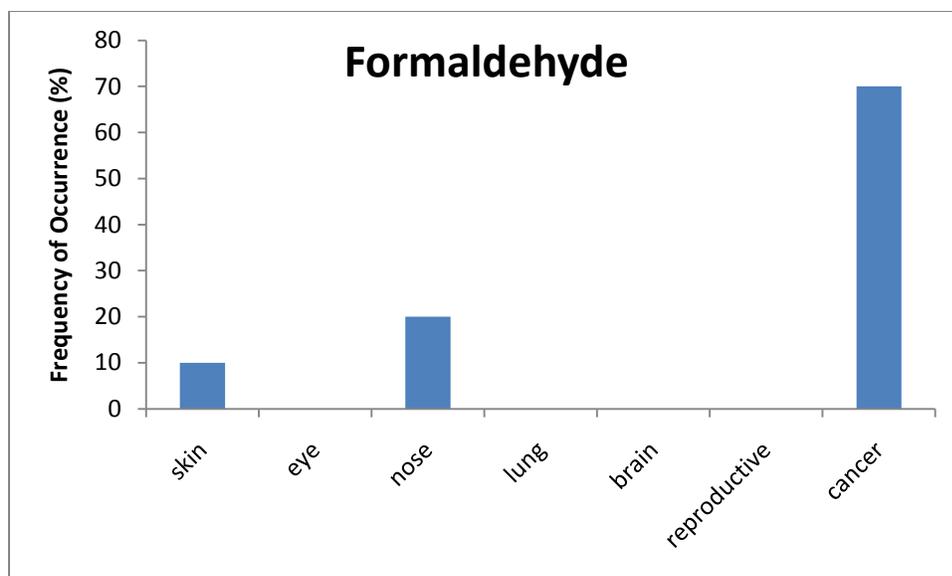


Figure 12. Frequency distribution of side-effects from exposure to formaldehyde.

References

- Andersen, M. et al. 1983. "Human response to controlled levels of toluene in six-hour exposure." Scandinavian Journal of Work Environmental Health. 9: 405-418.
- Anonymous. 1998. "Methyl methacrylate." World Health Organization (WHO). Concise International Chemical Assessment (CICAD). 4: 1-44.
- Almaguer, D. et al. 1997. "Health hazard evaluation report HETA 95-0118-2565, Martain Paving Company, Yeehaw Junction, FL." *Government Reports Announcements and Index*.
- Altenkirch, H. 1978. "Experimental studies on hydrocarbon neuropathies induced by methyl-ethyl-ketone (MEK)." Journal of Neurology. 219: 159-170.
- Autain, J. 1973. "Toxicity and health threats of phthalate esters." *Environmental Health Perspectives*. 1-26.
- Aydin, O. et al. 2002. "Effects of methyl methacrylate on nasal cavity, lung, and antioxidant system (an experimental inhalation study)." Toxicology Pathology. 30 (350-356).
- Baran, R. 2002. "Nail beauty therapy: an attractive enhancement or a potential hazard?" *Journal of Cosmetic Dermatology*. 1:24-29.

- Barlow, N. et al. 2004. "Male reproductive tract lesions at 6, 12, and 18 months of age following in utero exposure to di(n-butyl) phthalate." *Toxicology Pathology*. 32: 79-90.
- Blair, A. et al. 1990. "Mortality from lung cancer among workers employed in formaldehyde industries." *American Journal of Industrial Medicine*. 17: 683-699.
- Blount, B. et al. 2000. "Levels of seven urinary phthalate metabolites in a human reference population." *Environmental Health Perspectives*. 108:979-982.
- "CDC - NIOSH Pocket Guide to Chemical Hazards -Acetone." *Centers for Disease Control and Prevention*. Web. 04 Feb. 2011. <<http://www.cdc.gov/niosh/npg/npgd0004.html>>.
- "CDC - NIOSH Pocket Guide to Chemical Hazards -Formaldehyde." *Centers for Disease Control and Prevention*. Web. 04 Feb. 2011. <<http://www.cdc.gov/niosh/npg/npgd0004.html>>.
- "CDC - NIOSH Pocket Guide to Chemical Hazards -Toluene." *Centers for Disease Control and Prevention*. Web. 04 Feb. 2011. <<http://www.cdc.gov/niosh/npg/npgd0004.html>>.
- "CDC - NIOSH Pocket Guide to Chemical Hazards -Phthalate." *Centers for Disease Control and Prevention*. Web. 04 Feb. 2011. <<http://www.cdc.gov/niosh/npg/npgd0004.html>>.
- "CDC - NIOSH Pocket Guide to Chemical Hazards -Methyl methacrylate." *Centers for Disease Control and Prevention*. Web. 04 Feb. 2011. <<http://www.cdc.gov/niosh/npg/npgd0004.html>>.
- "CDC - NIOSH Pocket Guide to Chemical Hazards -Methyl Ethyl Ketone." *Centers for Disease Control and Prevention*. Web. 04 Feb. 2011. <<http://www.cdc.gov/niosh/npg/npgd0004.html>>.
- Chan, P. et al.1988. "Two-year inhalation carcinogenesis studies of methyl methacrylate in rats and mice: inflammation and degeneration of nasal epithelium." *Toxicology*. 52:237-252.
- Chang, H. et al. 2003. "The effects of co-exposure to methyl ethyl ketone on the biological monitoring of occupational exposure to N,N-dimethylformamide." *Int. Arch. Occup. Environ. Health*. 76:121-128.
- "Consumer Alert - MMA." Web. 04 Jan. 2011. <http://www.beautyweb.com/consumer_alert_mma.htm>.
- Cosmetic Ingredient Review Board. 2002. "Amended Final Report on the Safety Assessment of Ethyl Methacrylate." *International Journal of Toxicology* 21.2: 63-79.
- Dalton, P. (1997). "Perceived odor, irritation, and health symptoms following short-term exposure to acetone." *American Journal of Medicine* 31(5): 558-569.

- Dearfield, K. et al. 1989. "Analysis of the genotoxicity of nine acrylates/methacrylate compounds in L5178Y mouse lymphoma cells." *Mutagenesis*. 4:381-393.
- Decker, D. et al. 1983. "Worker exposure to organic vapors at a liquid chemical waste incinerator." *Ind. Hyg. Assoc.* 44:296-300
- DeCoster, J. (2004). *Meta-analysis Notes*. Retrieved <March,18, 2011> from <http://www.stat-help.com/notes.html>
- Dick, R.B. et al. 1989. "Neurobehavioural effects of short duration exposure to acetone and methyl ethyl ketone." *British Journal of industrial Medicine*. 46: 111-121.
- Dick et al. 1984. "Effects of acute exposure of toluene, methyl ethyl ketone on psychomotor performance." *International Archives of Occupational and Environmental Health*. 54:91-109.
- Donald, J. et al. 1991. "Reproductive and developmental toxicity of toluene: a review." *Environmental Health Perspectives*. 94: 237-244.
- Dormer, W. et al. 1998. "Methyl Methacrylate." Concise International Chemical Assessment Document 4. Environmental Health Directorate, Health Canada for the United Nations World Health Organization.
- Ernstgard, L. S., B. Warholm, M. Johanson, G. (2003). "Sex differences in the toxicokinetics of inhaled solvent vapors in humans 2.2 propanol." *Toxicology and Applied Pharmacology* **193**(2): 158-167.
- Esther, J. et al. 1994. "Spontaneous abortions among cosmetologists." *Epidemiology*. 5:147-155.
- Fujino, A. 1992. "Biological monitoring of workers exposed to acetone in acetate fibre plants." *British Journal of Medicine*. 49:654-657.
- Geller, I. et al. 1979. "Effects of acetone, methyl ethyl ketone, and methyl isobutyl ketone on a match-to-sample task in the baboon." *Pharmacology, Biochemistry, and Behavior*. 11: 401-406.
- Gjolstad, M. T., S. Molander, P. (2006). "Occupational exposure to airborne solvents during nail sculpturing." *Journal of Environmental Monitoring* **8**(5): 537-542.
- Gieles, Dr Frans. "An Explanation of the Statistics Used in the Meta." *Niet Beschikbaar*. Web. 20 Mar. 2011. <<http://www.humanbeing.demon.nl/humanbeingsweb/Library/explanation.htm#Homogeneity>>.
- Glass, G. V. 1976. "Primary, secondary, and meta-analysis of research." *Educational Researcher* 5: 3-8.

- Goldberg, M. 1996. "Occupational risk factors for female breast cancer." *Occupational and Environmental Medicine*. 53:145-156.
- Hagberg, S. et al. 2005. "Exposure to volatile methacrylates in dental personnel." *Journal of Occupational and Environmental Medicine*. 2: 302-306.
- Halliday-Bell, J. et al. 2009. "Work as a hairdresser and cosmetologist and adverse pregnancy outcomes ." *Occupational Medicine*. 59:180-184.
- Haughton, A. et al. 2008. "Acrylate allergy induced by acrylic nails resulting in prosthesis failure." *J. Am. Acad. Dermatol.* 59:123-124.
- Heath, D. et al. 2009. "Interaction of endothelial cells with methacrylic terpolymer biomaterials." *Journal of Biomedical Materials Research Part B: Applied Biomaterials*. 289-297.
- Hecht, A. (1988). "Artificial Fingernails: Apply with caution." *FDA Consumer* **22**(1): 18-20.
- Herd-Losavio, M. et al. 2010. "A nested case-control of low birth-weight among cosmetologists." *International Archives Occupational Environmental Health*.
- Hersh, J.H. 1988. "Toluene embryopathy: two new cases." *Journal of Medical Genetics*. 26: 333-337.
- Houlihan, Jane. "Beauty Secrets | Environmental Working Group." *EWG Home | Environmental Working Group*. Web. 04 Jan. 2011. <<http://www.ewg.org/reports/beautysecrets>>.
- Hudak, A. and Ungvary, G. 1978. "Embryotoxic effects of benzene and its methyl derivatives: toluene, xylene." *Toxicology*. 11:55-63.
- Jaakkola, M. S. et al. 2007. "Respiratory effects of exposure to methacrylates among dental assistants." *Allergy*. 62: 684-654.
- Jobling, S. et al. 1995. "A variety of environmentally persistent chemicals, including some phthalate plasticizers, are weakly estrogenic." *Environmental Health Perspectives*. 103: 582-587.
- Kanerva, L. et al. 1996. "Occupational allergic contact dermatitis caused by photobonded sculptured nails and a review of (meth) acrylates in nail cosmetics." *American Journal of Contact Dermatitis*. 7: 109-115.
- Karches, G. 1972. Health hazard evaluation. Hazard Evaluation Services Branch, NIOSH, Cincinnati, OH. Report No. HHE-72-22-31-34-24, 10 pages, 2 references.
- Kawai, T. et al. 1992. "Curvi-linear relation between acetone in breathing zone air and acetone in urine among workers exposed to acetone vapor." *Toxicology Letters*. 62:85-91.

- Kerns, W. et al. 1983. "Carcinogenicity of formaldehyde in rats and mice after long-term inhalation exposure." Cancer Research. 43: 4382-4392.
- Kersemaekers, W. et al. 1995. "Reproductive disorders due to chemical exposure among hairdressers." *Scandinavian Journal of Work Environmental Health*. 21:325-334.
- Kersemaekers, W. et al. 1998. "Assessment of exposure to solvents among hairdressers: reliability of a classification scheme and questionnaire." *Occupational Environmental Medicine*. 55:37-42.
- Klemme, J. 1985. "Chemical and mechanical trauma to the skin in a rubber fabricating facility." American Journal of Industrial Medicine. 8: 355-362.
- Kwapniewski, R. et al. 2008. "Occupational exposure to DBP among manicurists." *JOEM*.
- Kreiss, K. et al. 2006. "Risk factors for asthma among cosmetology professionals in Colorado." *Journal of Occupational Environmental Medicine*. 48:1062-1069.
- Lindbohm, M. 1990. "Spontaneous abortions among women exposed to organic solvents." American Journal of Industrial Medicine. 17: 449-463.
- LoSasso, G. et al. 2002. "Neurocognitive sequelae of exposure to organic solvents and (meth)acrylates among nail-studio technicians." Neuropsychiatry, Neuropsychology, and Behavioral Neurology. 15: 44-55.
- Luce, D. et al. 1993. "Sinonasal cancer and occupational exposure to formaldehyde and other Substances." International Journal of Cancer. 53: 224-231.
- Luderer, U. et al. 1999. "Reproductive endocrine effects of acute exposure to toluene in men and women." *Occupational and Environmental Medicine*. 56:657-666.
- Lundov, M. et al. 2010. "Formaldehyde exposure and patterns of concomitant contact allergy to Formaldehyde and formaldehyde-releasers." Contact Dermatitis. 63: 31-36.
- Marquardt, W. et al. 2008. "Toxicity potentiation by H₂O₂ with components of dental restorative materials on human oral cells." *Archives of Toxicology*. 82:21-28.
- Maxfield, R. et al. 1997. "Silica exposure in artificial nail application salons." Illinois Department of Public Health, Division of Epidemiologic Studies. P. 1-19.
- Matsushita, Y et al. 1969. "Experimental studies for determining the MAC value for acetone. Biological reaction in the "one-day exposure" to acetone." 11:477-484.
- McDonald, J. et al. 1987. "Chemical exposures at work in early pregnancy and congenital defect." *British Journal of Industrial Medicine*. 44:527-533.

- McElhatton, P. 2003. "Occupational exposures during pregnancy." Journal of Toxicology: Clinical Toxicology. 41: 407-409.
- McLaughlin, J. 1994. "Formaldehyde and cancer: a critical review." International Archives on Occupational and Environmental Health. 66:295-301.
- Moore, M. et al. 1988. "Genotoxicity of acrylic acid, methyl acrylates, ethyl acrylates, methyl methacrylate, and ethyl methacrylate in L5178Y mouse lymphoma cells." *Environmental and Molecular Mutagenesis*. 11:49-63.
- Morata, T. et al. 1993. "Effects of occupational exposure to organic solvents and noise on hearing." Scandinavian Journal of Work and Environment Health. 19: 245-254.
- Muiswinkel, W. et al. 1997. "Monitoring and modeling of exposure to ethanol in hairdressing salons." *Ann. Occupational Hygiene*. 41:235-227.
- NAILS Magazine." *NAILS Magazine : Dedicated To The Success Of Nail Professionals*. Web. 27 Apr. 2011. <<http://www.nailsmag.com/page/70218/market-research>>.
- Ng, T. et al. 1992. "Menstrual Function in workers exposed to toluene." *British Journal of Industrial Medicine*. 49:799-803.
- Nomiyama, K. et al. 1973. "Respiratory retention, uptake and excretion of organic solvents in man." *Int. Arch. Arbeitsmed*. 32:75-83.
- O'Donoghue, S.R. et al. 1988. "Mutagenicity studies on ketone solvents: methyl ethyl ketone, methyl isobutyl ketone, and isophorone." Mutation Research. 206: 146-161.
- Olsen, J. et al. 1984. "Occupational formaldehyde exposure and increased nasal cancer risk in man." International Journal on Cancer. 34: 639-644.
- Ong, C. et al. 1991. "Biological monitoring of occupational exposure to methyl ethyl ketone." *International Arch. Occup. Environ. Health*. 63:319-324.
- Parkinson, D. et al. 1990. "Health effects of long-term solvent exposure among women in blue-collar occupations." American Journal of Industrial Medicine. 17: 661-675.
- Pellizzari, E. et al. 1982. "Purgeable organic compounds in mother's milk." Bulletin of Environmental Contamination and Toxicology. 28: 322-328.
- Permegiani, L. a. S., C. (1954). "Occupational pathology of acetone: clinical manifestations, work environment and physiopathological research." Medicina del Lavoro **45**(8-9): 431-457.
- Piirila, P. et al. 1998. "Occupational respiratory hypersensitivity caused by preparations

- containing acrylates in dental personnel.” *Clinical and Experimental Allergy*. 28:1404-1411.
- Porter, C. et al. 2009. “Overexposed and under informed.” California Healthy Nail Salon Collaborative. P. 1-24.
- Quach, T., P. A. Doan-Billing, et al. (2010). "Cancer Incidence in Female Cosmetologists and Manicurists in California, 1988-2005." *American Journal of Epidemiology* **172**(6): 691-699.
- Rajaniemi, R. et al. 1989. “Percutaneous absorption of methyl methacrylate by dental technicians.” *British Journal of Industrial Medicine*. 46: 356-357.
- Reutman, S., et al. 2009. “A pilot respiratory health assessment of nail technician: symptoms, lung function, and airway inflammation.” *American Journal of Industrial Medicine*. 52:868-875.
- Roelofs, C., L. S. Azaroff, et al. (2007). "Results from a Community-based Occupational Health Survey of Vietnamese-American Nail Salon Workers." *Journal of Immigrant and Minority Health* **10**(4): 353-361.
- Rogan, W. 1996. “Pollutants in breast milk.” *Arch. Pediatra. Adolesc.* 150:981-990.
- Rudel, R. A., K. R. Attfield, et al. (2007). "Chemicals causing mammary gland tumors in animals signal new directions for epidemiology, chemicals testing, and risk assessment for breast cancer prevention." *Cancer* **109**(S12): 2635-2666.
- Sallmen, M. et al. 2008. “Reduced fertility among shoe manufacturing workers.” *Occupational Environmental Medicine*. 65: 518-524.
- Satoh, T. et al. 1996. “Relationship between acetone exposure concentration and health effects in Acetate fiber plant workers.” *International Archives of Occupational and Environmental Health*.68: 147-153.
- Sauni, et al. 2008. “Occupational asthma caused by sculptured nails containing methacrylates.” *American Journal of Industrial Medicine*. 51:968-974.
- Schechter, A. et al. 1989. “Levels of polychlorinated dibenzofurans, dibenzodioxins, PCBs, DDT and DDE, hexachlorobenzene, dieldrin, hexachlorocyclohexans, and oxychlorane in human breast milk from the United States, Thailand, Vietnam and Germany.” *Chemosphere*. 18: 445-454.
- Schlumpf, M. et al. 2010. “Exposure patterns of UV filters, fragrances, parabens, phthalates, organochlor pesticides, PEDEs, and PCBs in human milk: Correlation of UV filters with use of cosmetics.” *Chemosphere*. 81: 1171-1183.

- Shigeta, S. et al. 1986. "Learning impairment in rats following low-level toluene exposure." *Industrial Health*. 24:203-211.
- Singh, A. et al. 2010. "Embryonic-fetal toxicity and teratogenic effects of a group of methacrylate esters in rats." *Journal of Dental Research*. 51:1632-1638.
- Sorensen, Janelle. "80,000 Chemicals in Everyday Products, But Who's Counting (No One) « MomsRising Blog." *MomsRising | Breadmakers and Breadwinners | Mom's a Star*. 28 July 2009. Web. 04 Mar. 2011. <<http://www.momsrising.org/blog/80000-chemicals-in-everyday-products-but-whos-counting/>>.
- Slater, T. et al. 2000. "Occupational respiratory symptoms in New Zealand hairdressers." *Occupational Medicine*. 50:586-590.
- "Substance Registry Services | Substance Registry Services | US EPA." *U.S. EPA Web Server*. Web. 04 Feb. 2011. <http://iaspub.epa.gov/sor_internet/registry/substreg/home/overview/home.do>.
- "Substance Registry Services | Substance Registry Services | US EPA." *U.S. EPA Web Server*. Web. 19 Mar. 2011. <http://iaspub.epa.gov/sor_internet/registry/substreg/home/overview/home.do>.
- Takeuchi, Y. et al. 1983. "An experimental study of the combined effects of n-hexane and methyl ethyl ketone." *British Journal of Industrial Medicine*. 40:199-203.
- Toren, K. 2007. "Asthma and methacrylates- gluing together the evidence." *Allergy*. 62:575-576.
- Tsigonia, A. et al. 2010. "Indoor air in beauty salons and occupational exposure of cosmetologists to chemical substances." *International Journal of Environmental Research and Public Health*. 7:314-324.
- Ukai, H. et al. 2010. "Occupational exposure to solvent mixtures: effects on health and metabolism." *Occupational and Environmental Medicine*. 51: 523-539.
- Van Engelen, J. et al. 1997. "Effect of coexposure to methyl ethyl ketone on n-hexane toxicokinetics in human volunteers." *Toxicology and Applied Pharmacology*. 144:385-395.
- Wigaeus, E. et al. 1984. "Intake, distribution, metabolism, and elimination of styrene in man. A comparison between single exposure and co-exposure with acetone." *British Journal of Industrial Medicine*. 41:539-546.
- Woolf, A. and Shaw, J. 1999. "Nail primer cosmetics: correlations between product pH and adequacy of labeling." *Journal of Toxicology. Clinical Toxicology*. 37: 827-032.

Appendix

Annotated Bibliography

Haughton, A. et al. 2008.

The principal author, Haughton, is a practicing dermatologist in New York State. The work is published in the Journal of American Academy of Dermatology. The paper is about how past use/exposure to acrylic nails can develop into an allergic reaction to medical procedures using methyl methacrylate. Methyl methacrylate monomers were outlawed by the U.S. FDA in 1974 after they were shown to cause contact dermatitis. However, they remain widely used in artificial nails, hearing aids, printing, dentistry and bone cement.

The paper cites a case study of a 52-year-old woman who developed aseptic loosening of the joint after the use of methyl methacrylate cement base for prostheses. The conclusion placed an emphasis on the dangers of cross-reactions to methacrylate monomers and the need for knowing past use of acrylics in patients.

Halliday-Bell, J. et al. 2009

This paper was published in the peer-reviewed journal; Occupational Medicine. The authors examined whether or not cosmetologists experienced higher instances of adverse pregnancy affects such as low birth weight, preterm delivery, small for gestational age (SGA) or perinatal death. The authors hypothesize that due to the inordinate levels of chemical exposure and awkward posture positions, cosmetologists might experience more pregnancy complications.

They conducted a logistic regression analysis and found that hairdressers experienced low birth rate, preterm delivery, SGA and prenatal death more than the control group (teachers) but that cosmetologists experienced higher instances of prenatal death and SGA. The study concluded that work as a hairdresser or cosmetologists may inhibit fetal growth and result in adverse pregnancy outcomes.

Quach 2010

Quach received her PhD from the University of California, Berkley where she studies cancer risks in nail salon workers and health disparities within the immigrant community. Quach compared the number of licensed manicurists to the number of documented cases of cancer found within that cohort. She used the license registration files to get the number of registered manicurists and used the California Cancer Registry to obtain the documented cases of “invasive cancer diagnosed among female residents of the state of California from January 1988 to December 2005. Quach discarded those with multiple licenses and men.

She used a Poisson regression model to examine 325,228 licensed women in California between 1977 and 2005. She recognized 9,044 newly diagnosed cases of cancer. The results failed to demonstrate a statistically significantly greater occurrence of cancer in manicurists.

Rudel, R. et al. 2007

Rudel has a Masters, Attfield has a bachelors of science, Schifano has a bachelor of arts and Brody is the only author with a PhD. The study was published as a supplement to *Cancer in Environmental Factors in Breast Cancer*. The authors conducted an extensive analysis of suspected carcinogens and made the findings publically available at www.silentspring.org/sciencereview. Basically, if a chemical was found to result in cancer of the mammary gland in at least 1 study, it was added to the list.

Since a typical bioassay (the best known way to identify potential human carcinogens) costs around an average of \$2 million, the authors wanted to extrapolate upon small groups of animals as a predictor for cancer. The paper describes the extensive database and the details of all their resources and where the studies came from. In the end, 216 chemicals made the list.

Of those 216 chemicals, “29 are produced in the US greater than 1 million lb/year, 35 are pollutants of indoor/outdoor air, 25 have involved occupational exposures to greater than 5,000 women, 10 are FDA food additives and 73 are or have historically been present in consumer products.” All of this information is detailed in tables within the report. Any inconsistencies they had about the dangers of any chemicals were not applicable to nail salons.

Some other limitations include; many studies being cross-species analyses, not all chemicals that pose a risk to human health produced tumors in animals, and some characteristics within the animals were hard to interpret and might not mention mammary tumors specifically,

Roelofs, C. 2007

Cora Roelofs received her Sc.D in industrial hygiene from the University of Massachusetts, Lowell, where she works as research faculty. Her paper used surveys to gauge work-related health effects of nails salon workers. Almost 40% of manicurists in the US are Vietnamese so the surveys and the interviewers were bilingual.

Nail salons health and safety are regulated by OSHA, however, “only 18 nail salons were inspected by OSHA in 2005 (OSHA 812113).” Products can be fairly unregulated as well. For example, methacrylate producers, despite being advised not to put methacrylates in cosmetics, continue the unsafe practice. Understanding that manufacturers will continue to profit from dangerous chemicals until forced not to, California passed the Safe Cosmetics Act of 2005. As a result, any harmful health effects must be disclosed by the manufacturer.

The survey consisted of opened-ended questions aimed at pin-pointing work-related adverse health effects. They modeled the questions after questionnaires from the American Thoracic Society, the Protocol for European Community Respiratory Health Survey, and the Nordic Occupational Skin Questionnaire. In order to assess whether or not symptoms were work-related, all questions were followed up with asking if the symptoms got better with time off from work.

Over 8 months, 140 surveys were collected, 71 from nail technicians with 65 being female and 6 being male. The mean age was 34 and almost half were recent immigrants. They worked about 46 hours a week. 64% rated their health as “good”, 31% as “fair” and 4% as “poor.” 21% said they visited a doctor for work-related problems and 34% knew of others who did. The workers identified irritating products that made them feel uncomfortable.

It is important to keep in mind the “healthy worker bias.” This bias states that people who can work regularly are the fittest population, since the elderly and infirm can’t work and stay home. Therefore, we can make the assumption that if workers are feeling sick it is not because they were sick to begin with. 65% of those sampled rated their health as good. But when compared to the 85% of workers in all sectors who rate their health is good, 65% is a much lower number.

Dick, R. 1989

At the time this paper was written (1989), Dick was working for the Department of Health and Human Services. This is one of the older papers and it mentions “technical difficulties” with equipment used in analysis. No doubt the technology and testing methods have improved since then. This paper studied the neurobehavioral effects of short-term exposure to acetone and methyl ethyl ketone. The known effects of ketone are eye, nose, and throat irritation, headache, nausea, vertigo, lack of coordination, and changes in mood.

The experiment exposed men and women subjects to greater concentrations of acetone and MEK than had been used before in previous studies. The treatment included acetone at 250 ppm, MEK at 200 ppm, a combination of acetone a 125 ppm and MEK at 100 ppm and ethanol as a placebo. It was a randomized, double blind study. After exposure, the subjects were tested on visual alertness, the ability to multi-task, their reaction time, memory and steadiness (postural sway). None of the behavioral tests showed a statistically significant difference between the sexes.

The “results indicate some mild but detectable effects in the chemical treatment conditions on auditory tone discrimination tasks and in one chemical condition (acetone) in men only on the POMS test.” There was also an implication that acetone affects postural sway. The only statistically significant result was observed in a neurobehavioral test and a psychological test. As for MEK, no statistically significant effects were observed at 200 ppm. Nor were there any statistically significant effects as a result of the combinations of acetone and MEK.

Houlihan, J. et al. 2000

The authors worked for the Environmental Working Group. This was a brief report about the presence and dangers of phthalates in beauty products and gave a nice summary of current standards and practices on how toxic chemicals are regulated in the United States then recommended policy changes.

According to the CDC, 3 million women of childbearing age are exposed to DBP nearly 20 times greater than groups within the population as of 2000. These levels are above the federal

safety standard. But this standard is too low to offer any real protection because it is based on a 1953 study that did not examine birth defects in the test animals. The sheer volume of chemicals used in our environment today is astronomical. According to the authors, “there are currently 75,000 chemicals licensed for use in the US. Approximately 15,000 are sold in volumes greater than 10,000 lb per year.” The EWG decided to conduct their own survey of product safety.

The EWG looked at Rite-Aid and Drugstor.com and compared their stocked products to patent records of products containing DBP. They found 37 nail polishes and accessories from name brands like L’Oreal, Maybelline, Oil of Olay and CoverGirl which contained DBP. Patents of products with DBP expanded to include shampoos, lotions, deodorant and sunscreen. Even some oral pharmaceuticals contained DBP. Of all the manufacturers, Proctor and Gambel were the worst offenders.

As for environmental law, phthalates are categorized as toxic substances but companies are permitted to use unlimited amounts in cosmetics. “An environmental release of just 10 pounds of DBP must be reported to environmental authorities under the Superfund law. The cosmetics industry, in contrast, puts hundreds of thousands of pounds of DBP into nail polish each year, with no requirements for safety testing or reporting to anyone. In the 25 years of the Toxic Substances Control Act, the EPA has regulated exactly one toxic substance in a consumer product, lead in paint.” In 1976 the Toxic Substances Control Act made the EPA powerless to regulate the buying and selling of toxic chemicals . The law stated the EPA needed to prove “unreasonable risk of injury” in order to band a chemical from commerce. But the law paradoxically prohibits the EPA from ordering safety studies until the product “proves substantial or significant exposures are occurring, “(basically, a wait-and-see approach to public safety.)

The report recommends avoidance as a strategy as well as urging manufacturers to produce safer products. The authors think producers should label all their products containing phthalates. Finally, the EWG suggests the CDC conducts a long-term, biomonitoring initiative to look at synthetic chemicals in human tissue.

Heath, D.E. 2009

Daniel Heath is a post doctoral researcher within the Department of Chemical and Biomolecular Engineering at the Ohio State University in Columbus, OH. I looked at this paper to give me a better idea of how methyl methacrylate (MMA) is used a biomaterial. This does not necessarily apply to nail salon workers but it may help in understanding what is mean when MMA is referenced as “bone cement.”

MMA as bone remodeling is widely available, stops disease transfer. MMA has also been used in hard and soft contact lenses. Heath wanted to create “a polymeric and cytocompatible biomaterial system with tunable mechanical properties through a copolymerization technique.” He eventually accomplished this by changing the transition temperature of the glass by adding different amounts of hexyl methacrylate and methyl

methacrylate. It was proved compatible with the human system when endothelial cells proliferated and spread in and around the polymer material without rejecting the material.

Nomiyama, K. et al. 1973

When this paper was written (1973), the authors were working in the Department of Hygiene at Gunma University School of Medicine in Maebashi, Japan. The goal of the study was to better understand how men and women retain, uptake and excrete organic solvents like benzene, toluene, n-hexane, trichloroethylene, acetone, ethyl acetate and ethyl alcohol. The test subjects consisted of 10, healthy Japanese young adults from each sex (about 20 volunteers total for each chemical except benzene, which only had 12 volunteers total). The volunteers were exposed to the chemical in an “exposure room” (60m³) for 2.7 to 4 hours. The concentration for each chemical was different.

Chemical	Exposure (ppm)	Duration (hours)
Benzene	52-62	4
Toluene	98-130	4
n-Hexane	87-122	4
Trichloroethylene	252-380	2.7
Acetone	127-131	4
Ethyl acetate	94-137	4
Ethyl alcohol	103-140	4

The longer a volunteer was exposed to a solvent, the respiratory retention of that solvent decreased. Women retained more trichloroethylene than men while men retained more acetone than women. Men showed larger uptakes of toluene, acetone and ethyl acetate than women and excreted more toluene and trichloroethylene than women.

It is clear than men and women metabolize organic solvents differently but not significantly. When compared to nail salons, this experiment only exposed volunteers to the solvents for 4 hours. This is half of an 8-hour regular work day and fails to demonstrate the long-term effects of such exposures. The chemicals used in the experiment are applicable to nail salons; however, this paper is very old and needs to be supplemented with more modern, long-term experiments.

Jobling, S., et al. 1995

The principal writer is a senior research fellow at Brunel University in London. The paper begins by discussing phthalates in the environment and what they are used for (making plastics flexible). It also discusses the sources of DBP in the environment. Not only are they present in the plastics that carry our drinking water, they also leach out of landfills and into our soil and groundwater. Other chemicals associated with plastics (alkylphenol and bisphenol-A) have been shown to be estrogenic and estrogens have been suggestive of interfering with mammary glands. Too much estrogen will be hazardous to the reproductive cycle, contributes to decreased sperm counts and is even linked to cancer.

Given the large amount of DBP in the water, the authors conducted a fish study. They measured estrogenicity by looking at the direct binding of the DBP to the fish's estrogen receptors. In most vertebrates (including fish and mammals), there are two types of estrogen receptors (ERalpha and ERbeta). Hormone receptors are flexible protein molecules that interlock with hormones. But the more things that are floating around that can bond to these receptors (DBP), the more opportunities there are for things to go wrong (cancer) (<http://e.hormone.tulane.edu/learning/docking-receptor-steroids.html> .) The authors studied the phthalates as well as anti-estrogens. The results showed that of the 20 chemicals tested, "9 reduced the binding of tritiated 12B-estradiol (a form of estrogen) to the fish estrogen receptor." They also concluded that "BHA is six or more orders of magnitude less potent than 179-estradiol, and hence causes stimulatory effects on both the human estrogen receptor and the growth of breast cancer cells." If a chemical did not display strong estrogenic qualities, the possibility that it is in fact an anti-estrogen was considered. (Anti-estrogens compete with estrogen hormones for a place in the estrogen receptor.)

Overall, the chemicals tested were weakly estrogenic. And since recent literature suggests estrogenic effects may be additive, there may exist thousands of weakly estrogenic chemicals in the environment. Humans are exposed to these chemicals through other routes besides through water. Ultimately, they found no evidence to suggest any effects on estrogen-responsive tissues given the total concentration of those chemicals. This could mean that in order to have an effect, a single DBP must be present in a very high concentration or thousands of DBPs must be present in low concentration to give an additive effect. Next I think we need to determine how many different types of DBP are present in nail salons or is there is just one.

EPA_1: Protecting the health of nail salon workers.

This 21 page report was written by the EPA in collaboration with Asia coalitions, OSHA, the FDA, other EPA offices and environmental justice organizations. The report includes how workers can minimize their exposure to the chemicals, recommends the use of Material Safety Data Sheets (MSDS), gives an example of a MSDS, and MMA fact sheet, and a table of 20 harmful chemicals and the side effects of overexposure.

In order to minimize inhalation, the report suggest installing a local exhaust ventilation system, re-sealing products that are not in use, avoid using excess amounts of products, and not working out of bulk containers. They recommend putting waste in a self-closing trashcan and changing the trash liners at least once a day. The report focuses on glove and mask use as well as washing hands before eating or drinking to avoid ingestion. Other "Best Shop Practices" include not smoking and training employees on the hazardous materials and the storage and handling of flammable liquids. The report mentions organic solvents specifically but only to warn against dry hands.

Overall, the report offered boilerplate safety recommendations. The phrasing of the report is very interesting. The introduction is carefully written to suggest that not only are nail care products innocuous in small amounts but corporations take the time to design products with

consumers' welfare in mind. When the report does mention "adverse health effects" it does not go beyond skin irritation or allergic reactions.

Kwapniewski, R., et al. 2008

The authors are from the Department of Nursing, School of Health Studies, Harvard School of Public Health and the CDC. The paper was accepted in the Journal of Occupational Environmental Medicine and begins with an introductory to phthalates (DBP). The experiment screened then compared pre and post-shift urine samples from 40 manicurists for DBP. They hypothesized that workers who wore gloves would have lower concentrations of DBP since phthalates are absorbed through the skin. They also wanted to test the idea that salons with exhaust ventilations systems mitigated the inhalation of DBP.

According to the Environmental Working Group's Not Too Pretty report, DBP was discovered in over half of all nail polishes available in the US and 90% of nail polishes sold in Korea. One such brand contained 59,815 ppm of DBP. The report reminds us that over 333,000 licensed manicurists work in the United States that over 90% are women and half are Vietnamese. DBP metabolize quickly, are, for the most part, released from the body within 24 hours.

Urine samples serve as a biomarker for DBP exposure so the authors obtained a pre and post-shift urine sample from 40 manicurists on a single workday. They also administered a questionnaire to delineate age, gender, and other work-related factors such as glove/ventilation use. The urine from 37 manicurists and survey data from 38 manicurists were evaluated. The survey found half the population was White while the other half was Vietnamese, 4 were men and the mean age was 35.8. 41% said they wear masks, 22% wear gloves and 76% eat within the salon.

The study concluded there was a significant change in DBP levels between pre-shift and post-shift urine samples (17.4 ng/mL). Glove use was concluded to be attributed to the reduction of cross-shift MBP concentrations and a suspected indicator for overall safer salon practices (if you go to the trouble to put on glove, you probably do the extra effort it takes to screw on all the lids tightly and take out the trash). As for ventilators, their use was not significant, according to this one study. It is also important to keep in mind that since DBP exposure can happen as a result of personal care products (deodorant, shampoo, fragrances) salon workers are being exposed to DBP through a variety of routes. This study was the first to examine DBP exposure in manicurists specifically and opens the doors to a variety of new questions.

FDA: FDA authority over cosmetics

This summary was taken from the Food and Drug Administration's website (<http://www.fda.gov/Cosmetics/GuidanceComplianceRegulatoryInformation/ucm074162.htm>) and outlines the major laws protecting consumers from harmful cosmetics. It outlines who has authority over recalls, inspections, customs and enforcement. According to this, "the two most

important laws pertaining to cosmetics marketed in the United States are the Federal Food, Drug, and Cosmetic Act (FD&C Act) and the Fair Packaging and Labeling Act (FPLA).” The FD&C Act is violated if a product contains poison, the product contains a filthy, putrid substance, the product is prepared in unsanitary conditions, and/or the container holding the product is poisonous. All of these violations, however, do not pertain to hair dyes; they are excluded from the act. Improperly labeled products are in violation of the act.

Unfortunately, “products and ingredients are *not subject to FDA premarket approval* authority (emphasis mine), with the exception of color additives.” This means companies can release whatever product they choose onto the consumers. Only after products are proven to be unsafe, will the FDA step in. Cosmetic companies bear all responsibility for validating the safety of the ingredients in their products. Manufacturers are free to use whatever ingredient they choose (except for color additives) provided the product is properly labeled.

The FDA does not have the authority to command a recall of a cosmetic product but does monitor companies who voluntarily remove dangerous products. The FDA is involved in Customs and Board Protection and reviews cosmetics under section 801(a) of the FD&C Act. The FDA also has the power to inspect manufacturing facilities, collect samples for testing and conduct research on the safety of cosmetics.

Finally, “manufacturers are not required to register their cosmetic establishments, file data on ingredients, or report cosmetic-related injuries to FDA. However, companies are encouraged to register their establishments and file Cosmetic Product Ingredient Statements with FDA's Voluntary Cosmetic Registration Program (VCRP).” I believe this summary does a good job of outlining FDA authority over cosmetics safety and highlights the limitations and strengths of the FDA and also the power wielded by manufacturers who are not “forced” but rather “encouraged” to do the right thing.

Kurtzweil, P. 2005

Paula Kurtzweil was a public relations representative for the FDA at the time this was written in 2005. She is a member of the Public Affairs Staff. *Fingernails: Looking Good While Playing Safe* was written to advise consumers on the basic safety hazards within nail salons. It explained that while we all know nail products contain harmful chemicals, the FDA does not remove them from the market because they are safe “when used as directed.” The report also reiterated that the FDA has no say in what goes on the market; they can only act after the product has been released for use/consumption. The report was most concerned about fungal or bacterial infections as a result of poor sanitation (unclean instruments, reusing water). It also examines allergic reaction of odor irritation due to salon products. MMA is also mentioned as being illegal and replaced by ethyl methacrylate although the author acknowledged ethyl methacrylate might be just as harmful. The report concludes by advising consumers to frequent licensed salons and be smart about acrylic nails. It also includes a hotline number to report adverse effects from nail salon products. Nothing new, just PR material.

Tsigonia, A. et al. 2010

The principal author works for the Department of Hygiene and Epidemiology at the Athens University School of Medicine. The peer-reviewed article was accepted to the International Journal of Environmental Research and Public Health. This study measured the amount of volatile organic compounds (VOCs), methacrylates, phthalates and formaldehyde in four randomly selected beauty salons.

They looked at whether or not the salons had facial treatments, body treatments, nail treatments and ventilation patterns. They also monitored windows and air-conditioning units. "VOCs were collected in charcoal sorbent tubes, using sampling pumps (SKC 224PCTX8 and 224PCEX8)...The sampling duration was approximately 7–9 hours with an air flow of 0.6 L min."

Formaldehyde was measured in three of the four salons using detector tubes (Gastec No 91L). In these tubes, the air passes through chromatometric detectors which change color depending on the concentration of the specific parameter (formaldehyde).

The results measured in the salons, on an 8-hour basis, showed significant variation between each salon. "More specifically, the concentrations ranged between 100 and 1,450 $\mu\text{g m}^{-3}$." This variation depended on the products used and the number of treatments that were carried out, as well as ventilation. As a result, "cosmetologists may be exposed to high concentrations of a mixture of volatile organic compounds at levels that can cause symptoms or discomfort." The most predominant organic compounds found within the salon include, toluene, xylene, esters and ketones (ethyl acetate, acetone, *etc.*) which are used as solvents. Formaldehyde, however, was not detected in any of the four salons. The authors advise, "our findings should be interpreted with caution since chemical exposure conditions in beauty salons are incredibly diverse and variable and any indoor environmental monitoring survey might be far from complete." They ultimately recommend switching to safer products as a short-term fix to the VOC problem within beauty salons.

Ng, Foo and Yoong 1992

Two of the three authors worked for the Department of Community, Occupational and Family Health at the National University of Singapore at the time this paper was written and accepted to the British Journal of Industrial Medicine. The authors examined occurrences of menstrual disorders in women who were exposed to toluene and women who were not, to the best of their knowledge, exposed to large amounts of toluene. Women working in the production of electrical insulating materials have reported that the women experienced a greater frequency of polymenorrhoea, dysmenorrhoea, and irregular cycles than controls. "Prolonged and heavy bleeding was more frequent in women exposed to benzene, toluene, and xylene" but since these women were often exposed to several chemicals at once, it's hard to know what how toluene ranks in responsibility. So, this study looked at women who were exposed only to toluene.

The workers were surveyed to determine who smoked, drank and whether they were exposed to high concentrations of toluene or low concentrations of toluene. The health effects of

those 311 women were then compared with the health problems of women in a control group. In this case, it was women who frequented a local health center. Menstrual problems were characterized by excessively long or short menstrual cycles. After excluding women over 40, “rates of menstrual disorders were studied in 231 female production workers with high exposure to toluene (mean 88 (range 50-150 ppm) in a factory manufacturing audio speakers and compared with a control group of 58 female production workers in other departments in the same factory who had little or no exposure to toluene (0-25 ppm).” No statistically significant differences were found in the frequencies of cycle irregularity or alterations in the amount or duration of menstrual flow between the group that worked at the factory and the group that did not.

This study contradicted earlier studies that state the presence of toluene results in more menstrual disorders. One reason for this might be that the “control group (women who did not work at the factory)” is from a lower socioeconomic background and probably work in factories as well. They did not interview the control group; they merely used their menstrual irregularity data from the health center. SO the real answer should come from comparing women who were exposed to high concentrations of toluene and women who were exposed to low concentrations of toluene within the same factory to see if there were any significant differences in menstrual irregularity. As it turns out, there wasn't. This paper is a little dated.

Goldberg, M. et al. 1996

The authors are from the Occupational and Environmental Health Unit from Montreal. They wanted to explore the indices of breast cancer rates over the past two decades. The potential cancer-causing factor they were most interested in was occupational hazards associated with breast cancer. They looked at studies dealing with different job cohorts (beauticians, industrial workers, etc...) The authors hypothesize that since “women have taken a more active role in the workforce since the 1960s, it is possible that the secular increases in incidence rates may be related in part to exposure to carcinogens in the workplace.”

The authors began by researching the Medline database for every paper that was published about cancer between 1971 and 1994 in 20 journals. They relied on a previous study done by Zahm who researched the same thing but only up until 1990. They reviewed 147 reports from 115 different studies.

The most applicable results concern cosmetologists and beauticians. They showed a 20% increased risk of cancer with significantly increased relative risk. The research sites exposure to “potentially toxic agents, such as organic dusts (hair), hair dyes, organic solvents (in nail products, settings, lotions, and hair sprays), and detergents” as a reason for the increased risk. The authors believe organic solvents are linked to breast cancer. The authors best convey how this works when they state, “the suggested mechanism is through migration of these lipophilic substances (organic solvents), and their metabolites, to adipose tissue in the breast where they can be stored, absorbed into the apocrine glands, possibly biotransformed, and then excreted into the ductal systems where they may remain in contact with the parenchyma for considerable

amounts of time, thereby initiating or promoting carcinogenesis.” The studies they found showed some organic solvents (benzene, 2-dibromoethane, dichloroethane, 2-dichloroethane, methylene chloride (benign tumours), styrene, trichloropropane, and vinyl chloride) were shown to be carcinogenic in rats and mice.

The studies lend support to the hypothesis that cosmetologists and beauticians are at an elevated risk for breast cancer given their exposure to toxic chemicals and organic solvents. However, given the heterogeneity of many of the cohorts, it is difficult to tease apart sex-specific chemicals.

Blount et al. 2000

The main authors work at the National Center for Environmental Health. Their paper was accepted by the peer-reviewed journal, *Environmental Health Perspectives*. Since phthalates rapidly metabolize and quickly leave the body through excretion they are not known bioaccumulators. However, given the increased presence of phthalates as well as the increased concern over their potential dangers, the authors wanted to establish a baseline of phthalate presence in the human populations.

The authors collected 289 urine samples from adults from the Third National Health Survey between 1988 and 1994. There was almost an equal number of men and women across age groups but weighted toward minority groups. The phthalates monoesters found most commonly in the urine samples were MEP (16,200 ppb, 6,790 µg/g creatinine), MBP (4,670 ppb, 2,760 µg/g creatinine), and MBzP (1,020 ppb, 540µg/g creatinine), which reflect exposure to diethyl phthalate (DEP), DBP, and BzBP. The authors take care to mention that DEP and DBP are common ingredients in hair and nail products. The most startling result was that women of childbearing age (20-40 years old) had “significantly higher urinary levels of MBP and other sex/age groups.”

This research is added support to the ideas that not only are phthalates more prevalent than we had previously imagined but women, particularly women of childbearing age are most vulnerable.

Donald, J.M. 1991

The author’s work was published in the peer-reviewed journal, *Environmental Health Perspectives* and sought to conduct a meta-analysis to determine the developmental toxicity of toluene. The author mentioned where toluene is found (including cosmetics, nail polish and gasoline) and stated OSHA’s acceptable concentration in the air over an 8-hour workday is 100 ppm (375 mg/m³). Over time, 80% of toluene is absorbed by the lungs and between 4 and 8% is expired while less than 1% is excreted. Toluene is metabolized in humans and other mammals by the liver.

Several studies reported the ill effects of toluene transfer to the fetus. One study found about 10% of inhaled toluene is transferred to the fetus. The most commonly reported side effect of toluene was discovered to be the retardation of somatic growth as well as lowered fetal

bodyweight. When pregnant mice were exposed to toluene at 133 ppm (above the acceptable legal limit) they experienced a significant increase in malformations of the fetus. In contrast to that, one study by Courtney et al. found toluene had no effect on body weights.

A significant increase in embryonic mortality occurs at the following dose levels; 0.9, 1.5, and 3 mg/kg/day. In the author's own words, "it is clear from the results of studies in animals that toluene is associated with developmental toxicity. Toluene via inhalation for 6 hr/day at dose levels producing no significant maternal toxicity in a well-controlled and well-conducted study caused retardation of both fetal and postnatal development."

This paper gives us a clear picture of toluene's effect on developing fetuses as well as the acceptable legal limit of toluene inhalation.

Aydin, O. et al. 2002

The authors are from medical universities in Turkey as well as a school of dentistry. The paper was published in the peer-reviewed by the *Society of Toxicological Pathology*. The authors wanted to determine the effect methyl methacrylate (MMA) had on the lungs, the nose and antioxidants. MMA is commonly used as "bone cement" to produce dental prostheses and in orthopedic procedures. And while MMA has been found not be cancerous, previous clinical studies found MMA to cause numerous adverse health effects including irritation, dermatitis, stomatitis, asthma, liver problems, and disturbances to the nervous system. MMA most commonly enters the body through the lungs and once in the body, are attacked by antioxidants whose job it is to scavenge and get rid of foreign chemicals. Antioxidants (GSH and SOD) are suspected to be the body's defense against oxidative attacks.

The authors took 33 rats and separated them into 3 groups. Group A (11) was exposed to MMA in a poorly ventilated room, Group B (12) was exposed to MMA in a well ventilated room and Group C (10) was the control group which received normal air. After 30 days, the rats were killed and an autopsy was performed. The most common findings were multifocal hemorrhages and discolorations of the lung. The presence of alveolar macrophages was significant between groups A and C as well as A and B. The monomer used in mixing MMA escapes into the air, resulting in a noxious odor and harm operating room attendants. Besides harm to the lungs, this study also showed degeneration of the olfactory epithelium of rats in groups A and B, the two that were exposed to MMA. Finally, the authors demonstrated MMA is best at causing emphysema in poorly ventilated rooms.

The occupations most at risk for MMA exposure are neurosurgeons, orthopedic surgeons and dental personnel. Medical staff are sometimes exposed to MMA up to levels of 100 ppm. This is because MMA is often prepared in open bowls by personnel who are unaware of the toxic effects of MMA. Face masks do not prevent vapor inhalation of those monomers so better protection is necessary to protect the nose and lungs.

MMA is supposed to be banned so I think the next step, now that we have established MMA is terrible for you, is to figure out exactly how much is actually available in nail salons.

Dearfield, K. et al. 1989

The primary author is from the Health Effects Division of the U.S. EPA. The article was accepted into the peer-reviewed journal, *Mutagenesis*, an international journal concerned with the genetic change of living organisms and the biological and chemicals mechanisms responsible for that change. The paper looks at acrylate and methacrylate esters from industrial settings and examines them for genetic mutations (possible hints of cancer).

They tested 9 different compounds in lymphoma cells in mice then performed a mutagenesis assay to detect changes in the genetic make-up. If the mutagenesis assay showed mutant changes at a frequency twice as common as the normal background rate of mutations, the response was regarded as “positive” (that is, responsible for the mutation). In other studies, acrylate/methacrylate esters were showed to produce small-colony mutations in lymphoma cells. The results in this paper support previous studies’ hypotheses that the toxicity of these esters to an organism’s genetic composition is very real. Acrylate/methacrylate compounds affect small-colony formations by acting as a clastogenic mechanism. This means, acrylate/methacrylate compounds act as “mutagens which cause chromosome effects including breaks, rearrangements and changes in number.” Acrylate/methacrylate esters are, in fact, genotoxic agents *in vitro*. Lastly, acrylates were “generally more potent than their corresponding methacrylates.” The authors believe both these compounds to be genotoxic but think acrylates should take precedence over methacrylates when setting safety recommendations.

Singh, A. et al. 2010

The authors are both from the toxicology lab at the College of Dentistry, University of Tennessee, Memphis, TN. The paper was accepted to the peer-reviewed Journal of Dental Research. The purpose of the study was to determine whether or not 5 methacrylate esters, when administered at 3 different dose levels, affected fetal development. Acrylic resins were widely accepted by the dental association to construct denture based. AT the time this paper was written (1972), methacrylate vapors were regarded as less toxic than ethyl acetate but more toxic than acetone.

Singh et al. exposed gestating females to 5 different methacrylate ester monomers at three different dose levels. At the end of each pregnancy, the females were killed and the fetuses were examined for any malformations and weighted. Fetal deaths happened less frequently than all the other malformations but the ones that did occur, were observed only in groups treated with isodecyl methacrylate and acrylic acid. The highest dose of acrylic acid resulted in 3 dead fetuses. Fetal abnormalities, or teratogenicity, were statistically significantly present in all treatment groups. No gross abnormalities were observed in the control groups. Fetuses from the treatment groups were significantly smaller than the controls. More specifically, “administration of acrylic acid or a methacrylate ester to pregnant rats on days 5, 10, and 15 of gestation generally produced a dose-related increase in gross and skeletal abnormalities, and a reduction in fetal weight at birth.” The occurrence of abnormalities in rats treated with phthalates was the

greatest. Overall, ethyl methacrylate produced “significant embryopathic and tetragenic effects.”

Overall, acrylic acid, ethyl methacrylate and isodecyl methacrylate were the most harmful, but all methacrylate treatment groups experienced fetal abnormalities and low birth weights while the control experienced none.

Moore, M. et al. 1988

Moore works for the Mutagenesis and Cellular Toxicology branch of the EPA. The peer-reviewed paper was accepted to the journal, Environmental and Molecular Mutagenesis. It is highly technical and I think simply the abstract does the best job of summarizing the paper.

“A series of monomeric acrylate/methacrylate esters (methyl acrylate, ethyl acrylate, methyl methacrylate, and ethyl methacrylate) as well as acrylic acid were examined for genotoxic activity in L5178Y mouse lymphoma cells without exogenous activation. All five compounds induced concentration-dependent increases in mutant frequency. Small-colony, trifluorothymidine-resistant mutants were primarily induced, which suggests that these compounds may act via a clastogenic mechanism. This prediction was confirmed by the finding that all five compounds produced gross chromosome aberrations in mouse lymphoma cells. The two acrylates were much more potent in their response than acrylic acid. Methyl acrylate (22 *pg/ml*, survival = 18%) induced 385 mutants/106 survivors (total mutant frequency less the spontaneous mutant frequency) and 45 chromosome aberrations/ 100 cells analyzed (total aberrations less the spontaneous background). Ethyl acrylate (37.5 *pg/ml*, survival = 15%) induced 683 mutants/106 survivors and 48 aberrations/50 cells analyzed. Acrylic acid (500 *pg/ml*, survival = 22%) induced 245 mutants/106 survivors and 37 aberrations/100 cells analyzed. The two methacrylates required higher concentrations to induce a positive response.

Methyl methacrylate (2,799 *pg/ml*, survival = 11%) induced 230 mutants/106 survivors and 29 aberrations/200 cells analyzed. Ethyl methacrylate was extremely difficult to test because of a plateau in the dose response, over which the toxicity fluctuated from 2% to 37% survival. Positive responses (twice the spontaneous background) were only obtained at toxicity levels with less than approximately 20% survival. A concentration of 1,626 *pg/ml* (survival = 16%) induced 83 mutants/106 survivors and 11 aberrations/200 cells analyzed. The evidence suggests that the genotoxicity of these compounds is most likely due to a clastogenic mechanism.”

That being said, how does this relate to nail salons? Each chemical tested has some presence in nail salons and each chemical resulted in genetic mutations. These chemicals are potentially dangerous.

Satoh, T. et al. 1996

Satoh works for the Department of Hygiene and Public Health at the Tokyo Women's Medical College. The paper was accepted to a peer-reviewed journal and sought to clarify the relationship between occupational exposure to acetone (AC) and its health effects on workers. Acetone is considered to be one of the less toxic solvents. In the UK the exposure limit is 1000 ppm while in the USA it is 750 ppm.

To examine the effects of acetone, the authors studied 110 male AC-exposed workers and 67 non-exposed male workers. They began by establishing a baseline of health with a questionnaire to appraise subjective symptoms then asked both groups to perform a series of tests. The tests included neurobehavioral (5 total) and physical tests.

AC workers complained of headaches, nausea, faintness, weight loss and phlegm in the cold months as well as at night.

This study showed higher frequencies of subjective symptoms related to neurological effects in AC workers. There were also reports of chronic effects. An example of a neurological adverse effect as a result of AC exposure is delayed reaction time when exposure limits reached 500 ppm. Exposure to 250 ppm resulted in small but statistically significant differences between the AC workers and the control group. Symptoms of neurobehavioral effects seem to be the most sensitive ways of detecting adverse health effects of AC. This study demonstrated workers exposed to acetone had irritative and narcotic effects and a significantly higher presence of subjective symptoms. They concluded the current Japanese limit of 750 ppm is too high to prevent adverse health effects.

This paper did a good job establishing acetone as an irritant but not lethal or super deadly in any capacity.

Piirila, P. et al. 1998

The authors are from the Finnish Institute of Occupational Health in Helsinki, Finland. The paper was accepted into the peer-reviewed journal, *Clinical and Experimental Allergy*. Understanding that contact dermatitis respiratory problems caused by acrylics is common for dental professionals, the authors sought to report cases of respiratory hypersensitivity in dental staff during a 6 year period. 3 groups of acrylates are used by dentists.

The authors used a "skin-prick test" to figure out common environmental allergens as well as inhalation tests to determine exposure and respiratory distress. The results showed 12 patients (6 nurses and 6 dentists) to possess respiratory and mucosal hypersensitivity caused by acrylates. Of the personnel, 9 had asthma, 2 had rhinitis and 1 had laryngitis; all as a result of acrylate exposure. The results go on to outline the case study of 2 of the 12 patients in more detail. There are more recorded cases of asthma within the dental profession than the general occupation population. "According to the Finnish Register of Occupational Diseases, the annual

incidence of occupational asthma in 1990–95 was 18/100 000. The incidence of occupational asthma in dental workers was at the same time slightly higher, 23/100 000.”

The authors conclude this increase in asthma within the dental profession is a result of acrylate use. “The present paper demonstrates the increasing problem of dental personnel developing respiratory hypersensitivity diseases during exposure to acrylate compounds.” This is an important paper for nail salons because identical chemicals are used in that profession as well. It is reasonable to speculate that nail salon workers would be at risk for respiratory hypersensitivity and contact dermatitis.

Shigeta, S. et al. 1986

The authors are from the Department of Environmental Medicine and Occupational Health, School of Medicine, Tokai University. The paper was accepted by the peer-reviewed journal, *Industrial Health*. According to the authors, “Almost all of the neurobehavioral studies were investigations on the neurotoxicities of toluene over short- or long-term exposure in adult humans or animals. Thus, there have been only a few studies concerning the effects of toluene exposure during the brain development stage, and none on the effects of low-level toluene exposure during the brain-developing stage on learning has been made.”

In order to do this, they exposed the rats to toluene at a concentration of 100 ppm from the 13th day of gestation up until birth. Then, the offspring continued to be exposed to toluene for 7 hours every day. They then put the rats through learning/behavioral tests (Skinner Box) to determine how quickly they learned.

The results on avoidance learning showed no significant difference between the rats who were exposed to toluene and the rats who were not. “Learning acquisition of females, in both the control and the exposed group was very slow, and the mean avoidance rate remained below 70% throughout the test. Large magnitudes of individual variation in avoidance rate were recognized in both groups. The mean avoidance rate of the controls was higher than that of the exposed females. However, no significant difference was seen between the two female groups.” There were about 50 females and 50 males, half of each sex was HA/Wistar and exposed/not exposed to toluene. The male HA rats showed a noticeable learning impairment when exposed to toluene.

The authors concluded there needed to be further study to expound on the sex difference between the rats. Overall, the learning impairment was more apparent in the HA strain of rats rather than in the Wistar strain of rats. The concentration and length of toluene (for such a short-term study) is applicable to nail salon workers however, I would have liked to see more rats, given the large amount of learning patterns within each group. I think more rats would have given a better trend.

Kreiss, K. et al. 2006

Kreiss is a medical doctor whose paper was accepted by the peer-reviewed Journal of Occupational and Environmental Medicine. After receiving reports of asthma associated with cosmetologists, the authors explored the pervasiveness of work-related respiratory illnesses. The authors look at all areas of cosmetology (hairdressers, barbers, manicurists). For asthma, female hairdressers in other countries, like Sweden, displayed a mortality ratio of 332. For Colorado, the Health Department received 5 reports of work-related asthma from cosmetology.

The authors created a survey and sent it out to 3035 licensed cosmetologists (specifically 900 cosmetologists, 900 barbers, 900 manicurists). 1787 surveys were completed. Manicurists usually worked for less than 5 years whereas barbers and cosmetologists typically worked more than 5 years. The results showed the risk of asthma was increased from cosmetologists. The increased risk of asthmas for manicurists was associated with artificial applicators, acrylates, and cyanoacrylate glues. 67 respondents experienced post-hire asthma, 39 experienced an exacerbation of asthma due to work conditions.

This study showed marked morbidity from asthma or other respiratory illnesses as a result of health problems either acquired or made worse by work. I think the most interesting part of this paper is the discovery that manicurists tended to work less than 5 years in that area of Colorado. I wonder if that is because it is a profession that facilitates freedom of movement (offices all over the States) or if it is because the intensity of the chemicals make long-term work harder. And, since they don't work that long, it is hard to discover longer lasting adverse health effects? I think this is something that should be investigated further.

Hersh, J.H. 1988

The author is from the Child Evaluation Center at the University of Louisville, Kentucky. This was a case report from 1988 about 2 girls' developmental issues as a result of their mothers' abuse of toluene inhalation. This girls displayed central nervous system dysfunction, limb anomalies, growth deficiency and minor craniofacial abnormalities. One mother had a seven year history of toluene abuse and inhaled frequently during her pregnancy. The child's developmental retardation was recognized early in her childhood. "Psychological testing at three years two months indicated a mental age of three years two months with an IQ of 86 on the Stanford-Binet Intelligence Scale, Form LM." She also had mild speech impediments but no attention disorders.

With these 2 cases, as of 1988 we had 5 cases to support excessive toluene exposure *in utero* resulted in birth defects.

Ong, C.N. et al. 1991

The author worked for the Department of Community, Occupational and Family Medicine at the National University of Singapore. The paper was accepted into the peer-reviewed journal, International Arch Occupational Environmental Health. This studied look at the three most common ways to evaluate/monitor methyl ethyl ketone (MEK) while at work. The

three most common ways to assess exposure are through the blood, breath and urine. This paper does not go into the adverse health effects of MEK, merely the best way to evaluate how much is in the body. This paper is not that useful in our endeavor right now, but could help in understanding the methods of how they test of the presence of MEK.

Dick_1984

The paper was accepted to the peer-reviewed International Arch Occupational and Environmental Health. Dick was working for the CDC at the time and wanted to investigate how the exposure of MEK and toluene would affect men and women's motor skills. Toluene and MEK impacted the subjects central nervous systems at levels below 500 ppm so Dick decided to expose male and female volunteers to different concentrations of the chemicals (0-100 ppm) over different periods of time (1, 3 or 7 hours).

The results showed females exposed for up to 7 hours displayed significant performance problems on one cognitive test and did worse at multi-tasking as well as visual and tonal recognition tests. "In general, the results indicated that neither toluene at 100 ppm or MEK at 200 ppm seriously impaired behavioral performance on the tasks used in this study. The effects of toluene were at most marginal and were not as great as the effects of ingested alcohol (0.80 ml/kg)."

Muiswinkel, W. 1997

At the time this paper was accepted in the peer-reviewed journal, British Occupational Hygiene Society, the author was working for the Department of Air Quality at the Wageningen Agricultural University in the Netherlands. The authors wanted to investigate ethanol levels in hair salons after a study about the reproductive dangers experienced by salon workers was published. They wanted to understand what effects levels of exposure and design a model to predict and assess exposure to organic solvents.

The authors measured ethanol levels in 28 salons as well as personal exposure numbers of the employees. They also took auxiliary data from the salon workers. Over a 10 week time span, 114 salon workers were sampled and ambient air concentrations were collected. As expected, the higher the ambient air concentrations of organic solvents, the greater levels of solvents found in the employees.

The exposure levels were below Dutch standards for ethanol and comparable to drinking 7 ml of beer. The levels of detectable ethanol varied with the seasons and time and week. It was higher in the winter and on Fridays. Other solvents (methanol, acetone and dichloromethane) were identified but only ethanol was quantified. The authors recommend, "in future studies of solvent exposure of hairdressers, measurements should be carried out in all seasons and include different regions, and all working days of the week (including Saturday). Furthermore, other solvents than ethanol should be taken into account and different exposure routes (dermal exposure) explored."

Ukai, H. et al. 2010

The author's paper was accepted to the peer-reviewed journal, Occupational and environmental Medicine while the authors were working for the Department of Public Health in Kyoto, Japan. The authors investigated the health effect of mixed solvents on male industrial workers. They took a urinary analysis, workplace air analysis as well as subjective symptom survey from 303 male solvent workers and 135 non-exposed male workers. The solvent workers were exposed to a mixture of toluene (18 ppm), methyl ethyl ketone (16 ppm) isopropyl alcohol (7 ppm), and ethyl acetate (9 ppm). Toluene was the solvent with the greatest presence and the primary suspect of toxicity.

An analysis of the air showed toluene concentration as the highest but lower than the allowable limit. They authors received many complaints about eye, nose and throat irritation and upon further analysis found that toluene had to be responsible for these health effects, not MEK. The 2 organs hit the hardest by solvent toxicity are the liver and central nervous system. The authors found a significant increase in the prevalence of sleeping difficulties among the solvent-exposed workers. "Multivariate analysis showed that toluene was the most powerful determinant of eye irritation symptoms whereas MEK was the second most powerful one for nasal irritation." This is not because MEK does not result in irritation but because it was present in relatively low levels. Overall the study concluded toluene was main culprit in adverse health effects.

Slater, T. 2000

This paper was accepted to the peer-reviewed journal, Occupational Medicine and at the time the author was working for the Center for Public Health Research at Massey university in New Zealand. Hairdressers are known to be exposed to harmful chemicals that effect the respiratory system and as a result, the authors wanted to investigate the lung health of hairdressers in New Zealand.

The authors worked with 26 salons. 100 hairdressers and 106 non-hairdressers (managers and receptionists) total participated in the study. All employees were given a questionnaire designed to evaluate current respiratory conditions and whether or not they were a smoker. Each day, pulmonary function testing was performed on each worker. The results showed that while hairdressers seemed to be more prone to having asthma and shortness of breath, when the data was adjusted for age, gender and smoking, the gap between the experimental hairdressers and the controls disappeared. In the words of the authors, "this study did not find a consistent association between working in the hairdressing industry and occupational respiratory symptoms. The results from our study differ from those found in other cross-sectional studies which have found increased respiratory symptom prevalence in hairdressers, even after adjustment for smoking."

This study contradicts other studies of this nature so it would be good to see how many others stack up against it and why that is the case.

Fujino, A. et al. 1992

The authors' paper was accepted to the peer-reviewed *British Journal of Medicine* when they worked at the Department of Health Policy and Management at the Institute of Industrial Ecological Science in Japan. Acetone concentrations are measured in urine, air and blood. Concentrations of acetone within the urine, blood and air were measured in 110 male volunteers from three separate factories. The average concentration of exposure for the workers was 372 ppm. Just for reference, acetone has known physiological effects on human at 250 ppm. Overall, the best biological indicator for acetone exposure was urine. It is not only effective at conveying acetone exposure but can also be easily collected and processed. The authors therefore conclude that urine is the best method to determine acetone concentration in the body.

Kersemaekers, W. M. et al. 1995

The author's paper was accepted into the peer-reviewed *Scandinavian Journal of Work Environment Health*. The purpose of the study was to examine evidence for reproductive disorders in hairdressers by way of a literature review. The authors used the Medline database and search for reports on hair dyes, hairdressers, hair preparation and hair products between 1985 and 1993.

They divided the results into six sections (hair washing, bleaching, dying, perms, styling and other exposure) they outlines the chemicals of concern used for each procedure. The chemicals most applicable to our study of nail salons were ethanol, acetone and formaldehyde. Ethanol was an extremely important solvent in nail products. In hair spray for example, half the can (55%) is ethanol. Ethanol may also cause reproductive disorders and it very breathable. Acetone was the second chemical of concern. It is also a component of hairspray and a health hazard. In one study, a tiny increase in spontaneous abortion was recorded to have occurred in a group of women exposed to organic solvents. Formaldehyde has been shown to cause problems with menstruation and increase spontaneous abortion as well as retard fetal growth. Formaldehyde, however dangerous, is not as widely used in hair salons as it is In nail salons.

This literature survey documented all the known studies of adverse birth effects in hairdressers between the years 1985-1993. It identified several chemicals of concern but much of the research on this subject is limited to lab animals and not human subjects.

Morata, T. et al. 1993

The paper was accepted to the peer-reviewed, *Scandinavian Journal of Work Environment Health*. It looked at the effects of occupational exposure to organic solvents and noise on hearing impairment. The experiment was comprised of 50 unexposed workers, 50 workers exposed to noise, 51 exposed to noise and toluene and 39 exposed to noise and an organic solvent mixture. Hearing loss is an extremely common occupational risk. In the US alone over 1 million workers in industrial settings are approximated to have experienced work-induced hearing loss (moderate to severe). It is hypothesized that the risk of hearing loss is amplified with the exposure to organic solvents. This ototraumatic result was first proposed in 1984 and is possible. Organic solvents, known for their neurotoxic effects "can injure the

sensory cells and peripheral nerve endings of the cochlea, and, considering known solvent-related effects on the brain, a retrocochlear influence can also be expected.”

One 20 year-long study showed a 23% hearing loss in 319 chemical workers. This study looked at Brazilian workers from the printing and paint industry. The authors tested the employee’s hearing then assessed their exposure to organic solvents for one year. The main chemical used was toluene. The results show, “the prevalence of high-frequency hearing loss in the group exposed to noise and toluene simultaneously (53%) was higher than in the other groups: 8% in the unexposed group, 26% in the noise exposed group, and 18% in the group exposed to a mixture of solvents. The prevalence of high-frequency hearing loss observed in the solvent-mixture group (18%) was two times higher than in the unexposed group (8%).” These results are indicative of organic solvents’ ability to exacerbate hearing loss as well as the solvent’s ability to impact the auditory system. This would be an unexplored symptom not yet tested in nail salon workers.

Pellizzari, E. D. et al. 1982

The author’s paper was accepted to the peer-reviewed *Bulletin of Environmental Contam. Toxicology*. The authors were members of the Analytical Sciences Division at the Research Triangle Institute in North Carolina. They wanted to find the best way to evaluate the presence of environmental pollutants in the environment. They hypothesized breast milk would be an excellent bioindicator of the chemicals present in the environment. Breast milk might be good to use because it is easily collected, milk contains a lot of fat so fat-soluble pollutants are likely to be present in greater concentrations than in blood or urine and it comes in large volumes. Finally, the population of nursing women is large and they can be found in any geographic location.

Using gas chromatography/mass spectrometry, the authors analyzed any pollutants found in the milk. They found 12 women at different locations to donate their milk. As a result, 42 samples were then analyzed. They found a ton of chemicals (chart in the pdf, detailed and extensive.). They found pretty much all the chemicals we are concerned about in nail salons including acetone, ketone, methyls, ethyls, benzene, and toluene. Overall, mother’s milk proved to be a good bioindicator for environmental pollutants and contained several harmful synthetic chemicals.

Herd-Lo Savio, M. L. et al. 2010

This paper was accepted into the peer-reviewed journal, *International Arch Occupational Environmental Health* very recently (2010). This study attempted to tease apart specific tasks that could possibly be linked to low birth weights. Where women who performed certain jobs like dying or styling more likely to experience birth defects? Past researchers have found loose correlations between cosmetologists and low birth weights but they did not look at specific tasks performed.

The authors conducted a nested case-control study where they collected past work histories from cosmetologists who experienced low birth weights and collected confounding factors “such as time spent standing and glove use that could not be obtained from existing records.” They obtained 125 participants and 158 survey takers. The results showed how often

the workers employed certain tasks. The most frequent task was waxing, styling, washing and cutting. Most cosmetologists do not perform nail-related tasks so I don't think we can make many inferences about nail salon employees from this survey. Some caution; the response rate for this study was very low.

In the end, "no significant associations were found between occupational tasks of cosmetologists and low birthweights."

Kersemaekers, W.M. 1998

The authors paper was accepted to the peer-reviewed *Journal of Occupational Environmental Medicine*. The purpose of the study was to evaluate the reliability of a classification scheme used to predict reproductive disorders in hairdressers. Studies to evaluate this kind of thing rely heavily on questionnaires. This author wanted to use a few key questions to determine the level of ethanol exposure. The two questions were; Do you set waves? (yes or no) Did your salon have a ventilator? (yes or no).

The results showed a "mean ethanol concentration of 11.8% (high exposure group) and 7.4% (low exposure group)." I understood the point of this study to effectively show how much ethanol hairdressers were exposed to (high or low) based on 2 questions that would influence that exposure.

McDonald, J.C. et al. 1987

The paper was accepted to the peer-reviewed *British Journal of Industrial Medicine* when the authors were based in Montreal. The aim of the study was to examine birth defects that occurred as a result of chemical exposure early in the pregnancy. The work history of 300 women who recently experienced a congenital birth defect were paired with 301 women whose children were both without defects. The chemicals that most concerned the authors were organic solvents. Previous studies connected solvents with central nervous system defects and cleft palates. The survey was not only meant to examine a link between organic solvents and birth defects but also to supplement a lack of knowledge, in general, about spontaneous abortion, still births and premature births.

The survey looked at women who worked for 30 hours or more each week from the time of conception until the end of the 12th week of pregnancy. The data were analyzed in case-referent pairs by type of malformation and type of exposure in terms of intensity and nature.

The results showed aromatic solvents were linked to a suspicious excess of cases. More specifically toluene and to a lesser extent, aromatic solvents were of the principal chemicals of concern. Organic solvents have been showed to cross from the mother to the placenta. Overall, the data in Montreal suggests up to 30% of women who are pregnant have experienced some form of occupational exposure to organic solvents.

Chang, H.Y. et al. 2003

This paper is not 100% relevant to nail salon hazards. It's just about how methyl ethyl ketone (MEK) influences bioindicators that are used to detect levels of exposure. N,N-dimethylformamide (DMF) is broken down by human and when found in urine, can be used as a biomarker. However, the authors were not sure whether or not the presence of MEK would influence the effectiveness of DMF. The results showed, "this study was able to examine the effect of co-exposure to MEK on the characteristics of biomarkers of DMF exposure."

Luderer, et al. 1999

The paper was accepted to the peer-reviewed journal, *Occupational and Environmental Medicine*. The authors wanted to explore the toxicity of toluene and its effects on men and women respectively. They hypothesized that toluene suppresses the pulsatile gonadotropin secretion of the luteinizing hormone (LH) and the follicle stimulating hormone (FSH). The legal limits to toluene exposure were based on previous studies that showed huge, global health problems instead of detecting subtle alterations.

In order to measure the subtle effects of toluene in men and women, the authors exposed men and women to 50 ppm of toluene for 3 hours (19% of the OSHA permissible exposure limit) as well as a placebo (sham group) then measured their blood and urine as well as LH and FSH suppression. They then ran an ANOVA analysis. The results showed exposure to toluene at that level did not suppress LH or FSH significantly in men or women. However, the authors detected a trend to a significant LH suppression in women as well as men when compared to the sham group. "The results further suggest that intermittent, acute exposures to concentrations up to 50 ppm toluene, which are separated by sufficient time for toluene to be cleared from the body, are unlikely to result in physiologically important changes in gonadotropin secretion."

In order to make fair comparisons to toluene levels in salons to these types of studies, it is imperative to find average levels of toluene exposure in nail salons. It is also important to keep in mind salon workers are constantly exposed to toluene 8 hours each day and may not take the number of breaks suggested by these papers to allow the chemicals to exit the bodies benignly.

Reutman, S.R. et al. 2009

The authors' work was accepted to the peer-reviewed *American Journal of Industrial Medicine*. The paper begins by outlining how acrylic nails are applied. The main monomer used is ethyl methacrylate (EMA) which largely superseded methyl methacrylate (MMA) in the United States. Salon workers mix acrylic polymer powder with liquid EMA into a paste then mold it onto the nail, filed down then painted. Ambient levels of EMA were detected at concentrations of 0.88 ppm in over 90% of cosmetology schools. The authors cite only 2 previous studies that attempted to survey the health of nail salon workers in Colorado and Boston (Kreiss and Roelofs).

This study assessed 82 cosmetologists chiefly recruited out of cosmetology schools and from student campuses. The participants filled out a health survey about their smoking and respiratory history then post shift urine samples and breath samples were collected. The

technicians were divided into 2 groups (ones who worked with acrylics and ones who did not). The results showed the experimental group experienced more wheezing and eye irritation than the control group but not significantly more.

Overall, the results were inconclusive but intriguing enough to demand further investigation. “these findings suggest lung function and airway inflammation may be adversely influenced by nail technicians’ work environments. Future research is indicated to: (1) confirm whether or not unselected groups of nail technicians are experiencing measurable respiratory health effects due to their workplace exposures; (2) identify which exposures confer potential risks; and (3) establish effective ways to reduce nail technicians exposure risks.”

Maxfield et al. 1997

This report was issued by the Illinois Department of Public Health and not published in a peer-reviewed journal. This report is a response to the concern that white powdered silica used in acrylic nails causes health problems. Silica overexposure has been connected to silicosis, lung conditions, contact dermatitis and asthma. The report had three main objectives; finding the exposure rate for 5 different salons in Illinois, figuring out if down-draft tables reduce silica levels and whether or not different filing techniques produce different exposure amounts of silica. A worker from the Health Department volunteered to have acrylic nails done in order to understand the process.

Workers wore a face mask that covered the mouth and nose but did not seal around the face. The nails were clipped, buffed then painted between 6-12 inches from the worker’s face for about 20-25 minutes. .

Manufacturers put different levels of silica in their products, ranging from 1-10 percent. The study’s methods consisted of monitoring nail technicians every fifteen minutes at each task as well as surveys and air testing instruments in each salon.

None of the salons measured exceeded the NIOSH limit for silica (50 micrograms per cubic meter time weighted 10 hours a day for a 40 hour work week) and filing technique did yield different dust rates. The report concluded that silica was within the legal limit and that acrylic nail application affects both clientele and nail workers.

Esther et al. 1994

This was the first study to look into cosmetology’s link to birth complications, specifically spontaneous abortions. Cosmetology employs over half a million women in the United States. This is about hairdressers not nail technicians but both come in contact with similar chemicals such as organic solvents. A second major component to the Esther study was whether or not long periods of standing impacted birth spontaneous abortions. Little is known about the risk of standing on spontaneous abortions.

This study surveyed licensed cosmetologists of child-bearing age in North Carolina in 1988. They mailed surveys out to 8,356 female cosmetologists between the ages 22 and 36.

They asked about the outcomes of pregnancies, the number of hours spent standing, whether or not they used gloves, what type of disinfectants were used as well as other jobs worked while pregnant.

The results showed 191 spontaneous abortions 1,058 live births. 81% of the abortions occurred within the first 12 weeks of the pregnancy. 36% of the women worked in other professions or as a homemaker. Spontaneous abortions accounted for 7.8% of the most recent pregnancies. The authors were not clear about whether or not this was statistically significant but I doubt it was. There are many factors which make it difficult to tease apart the true factors resulting in cosmetologists' spontaneous abortions. Over ¼ worked in other jobs besides cosmetology and they worked with a variety of chemicals in a variety of concentrations making it difficult to locate the true hazards.

Autian, J. 1973

The author's literature review was published in the peer-reviewed journal, *Environmental Health Perspectives*. The focus of this literature review was to determine the ecological and human health hazards of phthalates. Phthalate production in the United States was around 900 million annually at the time this paper was written and has been produced since WWII in greater quantities than PCPs or DDT. Phthalates esters are colorless and soluble in organic solvents and oils. This review took place in 1973, therefore most of the studies drawn on by the author are from the 1940s, 50s and 60s.

The first few phthalates are from industrial setting where esters are derived from the highly toxic phthalic anhydride. Even back then they recognized the toxicity and took care not to inhale the dust. However, the rest of the paper is dedicated to highlighting the lack of evidence for toxicity. The author states, "published literature on the subject of phthalate esters has indicated that these chemical agents are relatively nontoxic and should not present any health hazards to man. Animal experiments dating back to the Second World War have shown that the most frequently used phthalate esters have an extremely low order of acute toxicity."

The papers that do show birth defects or toxicity associated with phthalates are only when phthalates are used in very high concentrations. At higher concentrations there was kidney damage and stunted growth. Most all the studies surrounding the phthalates were considered "practically nontoxic." There were a few cases of birth defects. Phthalates effect on the environment were inconclusive based on this literature review.

The author concludes by asking, "do the phthalate esters present a health threat to the population, either as a direct consequence of exposure or indirectly through ecological disturbance? Definitive answers to this question cannot be given at this time. From the review, however, it can be stated that in general the phthalate esters have a very low degree of acute toxicity to animals and man."

Obviously this is a very dated study.