

Asthma from hair straightening treatment containing formaldehyde: Two cases and a review of the literature

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Abstract

We report two cases of formaldehyde-containing hair straighteners causing new onset asthma. Formaldehyde has been reported to cause asthma in other settings. The purpose of this article is to examine two cases of asthma in hairdressers exposed to hair smoothing products and to review the relevant literature on formaldehyde exposure and asthma. The results indicated that both subjects developed asthma from repeated occupational exposure to formaldehyde during hair treatments. Both subjects became unable to tolerate hair straightening activity in their vicinity. Formaldehyde-containing hair smoothing products are sources of exposure, and the risk of developing asthma is high in salon settings where hair straightening is performed using formaldehyde.

Keywords

Formaldehyde, hair straightening treatments, hairdresser, asthma, respiratory disease, irritant, sensitizer

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Introduction

Chemicals that are both irritants and sensitizers are dangerous in occupational settings. Formaldehyde from inhalation can cause adverse pulmonary effects and skin exposures can cause or induce pulmonary responses (NIOSH, 2011b). Short term, high level, or longer term low exposures can cause irritant asthma or cause or aggravate obstructive lung disease. The mechanism is either a direct irritant effect or immune system sensitization (Brooks, 2013; Delfino, 2002; NIOSH, 2009). Additionally, there is individual variation in reaction to any exposure. The immune response to chemicals can be affected by genetics, although there are differences in the susceptibility to chemical sensitization and hypersensitization (Corsini and Kimber, 2007).

Formaldehyde is both an irritant and a sensitizer. It can cause a proportion of those exposed to develop an abnormal reaction in normal tissue including asthma (ACGIH, 2001; Gupta, 1982; US National Research Council, 1981). Harmful exposure occurs through inhalation and or dermal absorption. Formaldehyde absorbed in the nose, upper airways, and

the lungs causes both upper respiratory and lower respiratory problems.

OSHA has found that many hair straightening (or smoothing) products contain formaldehyde, often identified by synonyms such as formalin, methanal, formalith, formol, or methylene glycol (formaldehyde dissolved in water). A larger list of formaldehyde synonyms used on labels and the Material Safety Data Sheets can be found by Dahlgren et al. (2012) and the California Department of Public Health (2011) hand-out for formaldehyde exposed workers (NIOSH, 2011a). Hair straightening products have been reported to contain high levels of formaldehyde in the United States and internationally (McCarthy et al., 2010; Maneli et al., 2014; Health Canada, 2011; OSHA, 2011). Individuals exposed to these products

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include hairdressers and salon workers as well as their clients.

Methods

We report two cases of asthma in hairdressers initiated and aggravated by the exposure to formaldehyde contained in a hair straightening product. Medical records for both individuals were reviewed along with the administration of a questionnaire and examination performed. Additionally, we reviewed both the literature on formaldehyde containing hair straighteners and the literature on the occupational asthma as caused or aggravated by formaldehyde exposure. Other cosmetics have been found to contain formaldehyde, such as nail hardening products, but were ruled out after questionnaire and examination (Boyer et al., 2013; de Groot and Veenstra, 2010; Hauksson et al., 2016).

Case 1

A woman hairdresser in her early 30s took a 1–2 h course to learn how to use the hair straightening product in 2010. After the course, she was allowed to buy a bottle of the hair straightening product. Depending on client's hair length, each bottle would provide between 10 and 15 treatments. This subject hairdresser performed up to two treatments a day in 2010 and 2011. The process involves applying the product solution, blow drying, and applying a hot iron. She noted a white cloud of smoke appeared during the heating portion of the treatment. This process created fumes that caused immediate irritating symptoms in the eyes, nose, and throat. As she regularly performed the hair straightening treatments, her throat became increasingly irritated and she developed sinus pain. Following 6 months of performing hair straightening with this irritating solution, her symptoms of severe sore throat, chest pain, and lightheadedness did not lessen as they had at first. The respiratory symptoms have continued to the present. In 2010, she sought medical advice from her general practitioner who noted wheezing and referred her to a pulmonologist who diagnosed chemically induced asthma. She did not have any prior history of asthma. She attempted to do a few more hair straightening treatments but finally had to give up, including being present in the salon when others were applying the formaldehyde-based hair straightening chemical. She is now on a long-acting steroid inhaler and a rescue inhaler due to persistent asthma. She is only working part time because of her respiratory symptoms. Prior to the onset

of her lung problems, she was easily able to exercise but she now becomes out of breath with slight exertion. She develops asthma attacks if exposed to many other chemicals, which did not bother her before her work around formaldehyde fumes. She has a daily dry cough. Her medical records indicate an enlarged thyroid. She has no other environmental or work exposures that are known causes of asthma. She denied using persulfate as a hair stylist. Other hair chemicals did not cause any symptoms until her asthma developed. She had to stop using ammonia containing hair dye after the onset of asthma. Before the formaldehyde exposure, she did not have any problem with these hair dyes. Her only symptomatic exposures were the hair straightening chemicals. She has no family history of asthma.

Case 2

A 26-year-old woman, with a background in beauty school and as a salon receptionist, received her cosmetologist license in 2010. The same year she went to a class sponsored by the hair straightening company. Similar to Case 1, the class was free with a purchase of a bottle of the solution, and instructors purported there was no formaldehyde in the solution. During the demonstration, there was smoke during the heating and blow-drying of the hair. She started performing the treatment 5–7 times a week and noted she could do as many as 100 treatments with one bottle of the solution. In the beginning, her symptoms included burning in the eyes, nose irritation, and a sore throat. After more and more use, the symptoms increased and her coughing became worse until it progressed into chest tightness. Her doctor noted blisters on her throat but she continued to perform the treatments. In 2012, she went to the emergency room and the emergency-room doctor diagnosed asthma. She had no prior personal or family history of asthma. She performed one formaldehyde hair straightening procedure after the diagnosis for a special client and became extremely ill, unable to breathe, and almost passed out. She had to completely stop performing these hair straightening treatments but her shortness of breath, wheezing and other symptoms persisted, including fast heart beat with possible heart disease and severe asthma attacks secondarily to almost all chemical exposures. She has developed several new allergies, and her thyroid is enlarged. She cannot exercise and cannot travel to the mountains or fly in an airliner due to the reduced oxygen present in these circumstances. Her medical records reflect two doctors diagnosing chemically induced asthma, one being a lung specialist.

Dose and treatment process

The level of formaldehyde in the air varies during the different phases of the formaldehyde hair straightening process. Both the hair stylists and customers are exposed to significant formaldehyde levels in the air at each step. Stylists first apply the solution, blow-dry the hair, and then flat iron (heat-treats at about 400°F) the hair. A follow-up conditioner, rinse, and blow dry is sometimes used. Oregon OSHA, in eight different cases, found average airborne exposure levels during application of hair straightening treatments using formaldehyde-containing solutions. The formaldehyde ranged from 0.059 to 1.88 ppm. The highest level in this study occurred during 26 min of the blow-drying step (McCarthy, 2010). NIOSH measured airborne formaldehyde during formaldehyde treatment and found levels of 1.3 ppm during application and 0.9 ppm during blow drying (NIOSH, 2011a). Airborne formaldehyde levels have been shown to reach 3.59 ppm during peak exposure in the blow-drying process. In a study of air formaldehyde levels by Pierce et al. (2011), the airborne exposure was shown to be slightly higher than levels Oregon OSHA and NIOSH measured, but the findings are consistent between the three studies. In a study comparing salons, environmental formaldehyde levels ranged from 0.09 to 0.16 ppm in four salons that used products versus 0.02 and 0.04 ppm in salons that did not use them. On measurement day, five salons performed one straightening treatment and one salon performed two straightening treatments (Petteffi et al., 2016). While we do not have air measurements of formaldehyde in our cases, we can deduce that the levels of formaldehyde experienced were elevated to higher levels than these three studies found for three reasons:

1. Stylists often performed more than one formaldehyde hair treatment per day. The aforementioned studies performed only one treatment to obtain the air levels.
2. Multiple salon workers were performing formaldehyde hair treatments throughout the entire day.
3. Salon workers occasionally performed formaldehyde hair treatments concurrently.

For illustrative purposes, a map of the Case 2 salon layout is shown in Figure 1. Both this salon and the salon depicted in the Pierce study point to the typical

layout in hair salons. Pierce sampled a number of areas within the salon, including the reception and up to 10 m away from the treatment areas and found significant formaldehyde levels throughout. In Case 2, multiple treatments were performed in different areas of the salon at the same time providing ample evidence that her exposure levels would have been significantly higher than the air levels reported in the three studies.

In the Pierce study, the mean concentration for Zone 1 measured in the immediate area of the stylist was 1.17 ppm and in zone 4, the mean concentration was 0.52 ppm. Combining Zones 2 and 3 gives a concentration of about 0.705 ppm. If all three stylists were performing hair straightening treatments, it is likely the concentrations within case 2 Zone 1 would rise to the levels exceeding those measured in the three studies. As described by case 2, not all stylists would perform treatments at the same time, that is, often times while one stylist was in an ending stage of the treatment another would be starting another case. The multiple treatments occurring simultaneously and building up during the day would result in higher figures of formaldehyde exposure than a single treatment as performed by Oregon OSHA, NIOSH, and Pierce. The air levels during blow-drying operations were air concentration of 3.47 and 1.05 ppm in the area where the hair stylist worked. Area samples 30 ft away from the actual hair straightening were elevated indicating that everyone in the hair salon was being exposed to formaldehyde at unsafe levels.

Pierce also demonstrated a time-weighted average in an approximately 6 h workday to show levels of a single treatment versus four treatments in zones 1–4. The product with the highest concentrations showed a significant increase in the levels of formaldehyde in the air with multiple treatments, at the OSHA 8-h permissible exposure limit (PEL) of 0.75 and well above the NIOSH 8-h recommended exposure limit (REL) of 0.016 (Figure 2). As described previously, simultaneous treatments in zones 1 and 4 would likely increase exposure to formaldehyde gas well above both the OSHA PEL and NIOSH REL for hairdressers in their respective zones. If each stylist performed two treatments per day as discussed in Cases 1 and 2, the levels of formaldehyde would undoubtedly rise in all zones of the salon. Certain susceptible individuals have been shown to have increased asthmatic symptoms to formaldehyde levels below those discussed here, including the OSHA PEL and NIOSH REL (Kim et al., 2001).

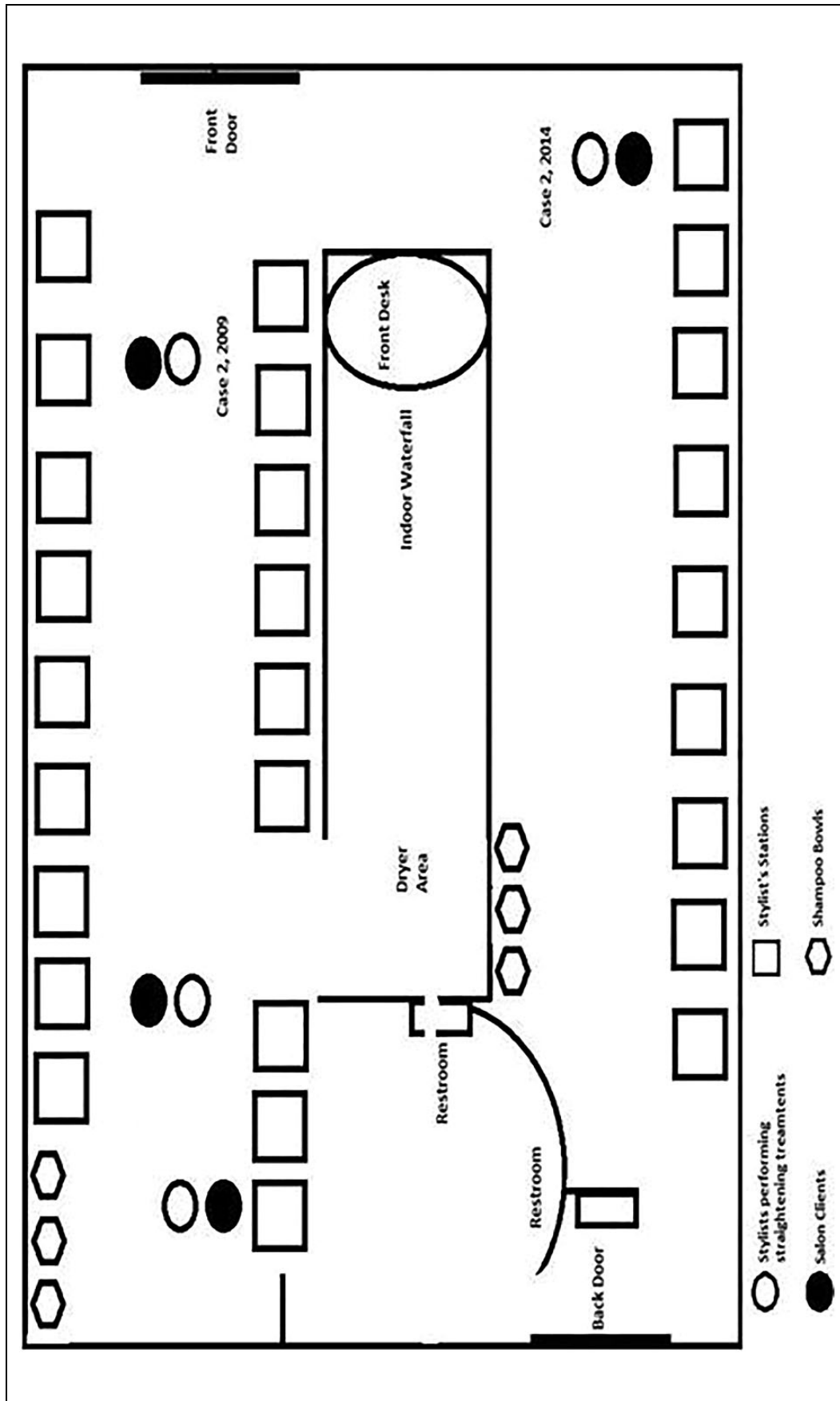


Figure 1. Case 2 salon layout.

Discussion

Hairdressers and salon workers are at significant risk for asthma due to the use of formaldehyde in hair straightening products. Of particular concern is the heating process undertaken during the blow-drying and flat-ironing stages because of the release of free formaldehyde (FHO). The form of formaldehyde in these products is called methylene glycol, otherwise known as formaldehyde, present in water solution. The air formaldehyde is in equilibrium with methylene glycol in solution (Matubayasi et al., 2007; Winkelman, 2003). Gas-phase inhalation occurs because the stylist is very close to the off gassing from the hair and is absorbing the formaldehyde through the skin. Both the stylist performing the treatment and the customer being treated are exposed to significant concentrations. Using products that contain the quantity of formaldehyde needed for effective hair straightening can result in worker exposure to unsafe levels of formaldehyde.

In Peteffi et al. (2016), formaldehyde exposure was not only measured and confirmed by environmental levels but also by a significant increase in urinary formaldehyde concentrations. Specifically concentrations at the end of the workday.

Irritant effects of exposure to formaldehyde-containing hair straightening products include eye, nose, and throat irritation; loss of smell; respiratory irritation and disease; cough; chest pains; dyspnea; and wheezing. Skin irritation was also reported, and symptoms of irritation in the mucous membranes of the upper airways and eyes have been documented in multiple studies (Kriebel et al., 1993; Malaka and Kodama, 1990). Other health complications, including DNA damage, cancer, and autoimmune diseases, have been reported in multiple studies (Galiotte et al., 2008; Dahlgren et al., 2012; Mazzei et al., 2010; Nielsen et al., 2013). Exposure to this chemical poses a significant potential risk because of its toxicity in the body, including the toxicity to the respiratory tract. Decreased pulmonary function has also been shown by those exposed to formaldehyde at low concentrations (Kilburn et al., 1989). Both individuals outlined in this report were exposed to high levels of formaldehyde on a daily basis for extended periods of over 2 years that caused damage to their lungs. To the authors' knowledge, this report documents the first case reports of asthmatic reactions to formaldehyde from hair straightening products. Hendrick and Lane (1975, 1977) and Hendrick et al. (1982) documented asthmatic reactions to formalin fumes in a hospital

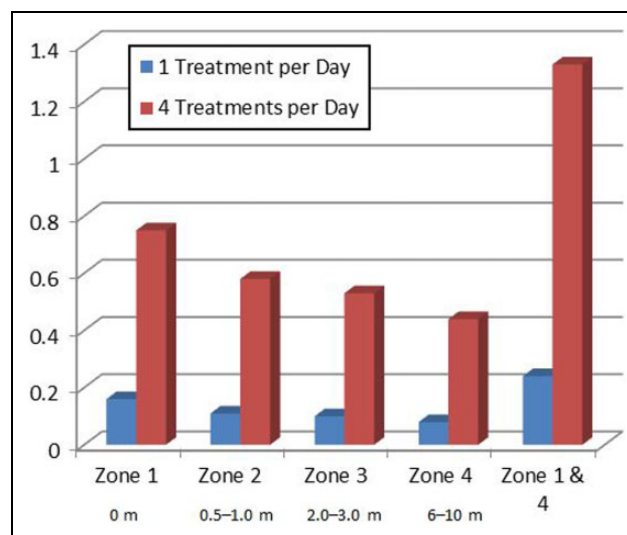


Figure 2. Time Weighted Average (TWA) concentrations of formaldehyde (ppm). Formaldehyde levels were measured under simulated conditions to a working salon at distance in meters.

worker, including a consistent dry cough and wheezing accompanied by breathlessness and rhinitis, late asthmatic responses to inhaled formaldehyde, and asthmatic reactions to formaldehyde fumes. Robertson et al. (1985) modeled occupational levels of formaldehyde and tested bronchial provocation, finding six subjects developed immediate asthmatic reactions and three developed late, classical occupational asthma caused by fumes. Irritant reactions to formaldehyde occur at concentrations found in the workplace, causing occupational asthma. These and other cases of asthmatic reactions due to formaldehyde exposure have been documented in other occupational reports as shown in Table 1.

There are other epidemiological studies that present evidence of formaldehyde induced asthma, including many studies on the relationship between respiratory health in children and indoor air exposure. This includes wheezing, doctor-diagnosed asthma, and breathlessness (Norback et al., 1995; Rumchev et al., 2002; Smedje et al., 1997). A meta-analysis by Yao et al. (2015) on the relationship between the concentration of formaldehyde and asthma in children showed a larger probability of asthma was associated with higher levels of formaldehyde.

The occurrence of two cases of asthma discussed here are the result of exposure to formaldehyde in the salons during hair straightening treatments. Given the individuals' history, medical records, and the

Table 1. Human studies of formaldehyde-related asthma effects.^a

Reference	Analysis Method	Subjects	Number of case study subjects	Exposure	Findings
(Lemiere et al., 1995)	Specific inhalation challenge (SIC)	Carpenter, chemist, and wood factory worker	3	Formaldehyde resin dust and gaseous at 1–3 mg m ⁻³	Two subjects presented asthmatic reactions to formaldehyde resin dust. one subject experienced asthmatic reaction to resin dust and formaldehyde gas
(Robertson et al., 1985)	Bronchial provocation tests	Printer/laminators, farmworker, medicine packer, core shop workers, manufacturer, plastic molder	15	1% formaldehyde: 2.3 mg m ⁻³ breathing zone 10%: 4.8 mg m ⁻³ breathing zone (1.87–3.9 ppm)	Three subjects presented occupational asthma due to exposure. Six workers developed immediate irritant-induced asthmatic reactions
(Hendrick and Lane, 1975)	Inhalation provocation tests	Nurse and pathologist	2	10–100% formalin in water	1 case of late asthmatic reactions to formalin fumes at no greater than 25%.
(Hendrick and Lane, 1977)	Peak expiratory flow (PEF), FVC, and inhalation provocation tests	Hospital staff: 12 nurses, 10 nursing auxiliaries, two assistants	5	Case 1: 10–100% formalin in water, cases 2–5: 10–25% formalin in water	2 late asthmatic responses to inhaled formalin for more than 1 week; 29% of the staff reported attacks of bronchitis since starting work
(Hendrick et al., 1982)	Pulmonary function tests and chest roentgenograms, and inhalation provocation tests	Follow-up of two nurses in 1977 study. One continued to be exposed and the other ceased exposure	2	10–25% formalin mixture	One nurse lost asthmatic sensitivity after ceasing exposure and the second nurse had persisting asthmatic response
(Kim et al., 2001)	Environmental assessment and specific inhalation challenge	Factory (crease resistant trousers) worker	1	Mean environmental exposure level: 0.06 ppm, short term 0.12–0.13 ppm	Severe occupational asthma. Persistent symptoms, decrease in lung function after 1 year
(Nordman et al., 1985)	Inhalation test, bronchial provocation tests	230 patients exposed to formaldehyde, multiple occupations and backgrounds	12	Formaldehyde solution of 0.5–2% for epicutaneous testing. Methacholine provocation tests positive response above 1.2 mg m ⁻³	12 considered to have bronchial asthma caused by occupational exposure to formaldehyde.

^a Asthmatic reactions after formaldehyde exposure are identified in seven different studies. The range of exposure and cases indicates the susceptibility of individuals to the sensitizer and irritant.

evidence of airborne formaldehyde levels during single treatments, it is highly probable that the levels experienced were higher than some reports reviewed above. Higher formaldehyde air levels are likely in the workplace with multiple treatments occurring simultaneously. Simulation studies reflect the minimum formaldehyde exposure for what hairdressers, their customers, and salon staff experience in a typical salon. The presence of formaldehyde in hair straightening products creates a hazardous environment for potentially thousands of people being exposed to a highly toxic and carcinogenic substance. Unfortunately, the labels do not always reflect the presence of the formaldehyde in the products. The companies use several synonyms to mask the presence of formaldehyde. Physicians should not rule out the occurrence of asthma as caused by exposure to formaldehyde in hair straightening products.

Authors' note

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References

- ACGIH (2001) *Formaldehyde. Documentation of the Threshold Limit Values and Biological Exposure Indices*, vol. 7. Cincinnati, OH: ACGIH, 1–26.
- Boyer IJ, Heldreth B, Bergfeld WF, et al. (2013) Amended safety assessment of formaldehyde and methylene glycol as used in cosmetics. *International Journal of Toxicology* 32(Suppl 4): 5S–32S.
- Brooks SM (2013) Reactive airways dysfunction syndrome and considerations of irritant-induced asthma. *Journal of Occupational and Environmental Medicine* 55: 1118–1120.
- California Department of Public Health (2011) *Formaldehyde: Fact Sheet HESIS*. Sacramento, CA: California Department of Public Health, California Department of Industrial Relations.
- Corsini E and Kimber I (2007) Factors governing susceptibility to chemical allergy. *Toxicology Letters* 168(3): 255–259.
- Dahlgren JD, Roback R, Dominguez M, et al. (2012) Case report: autoimmune disease triggered by exposure to hair straightening treatment containing formaldehyde. *Open Journal of Rheumatology and Autoimmune Disease* 3: 1–6.
- de Groot AC and Veenstra M (2010) Formaldehyde-releasers in cosmetics in the USA and in Europe. *Contact Dermatitis* 62(4): 221–224.
- Delfino RJ (2002) Epidemiologic evidence for asthma and exposure to air toxics: linkages between occupational, indoor, and community air pollution research. *Environmental Health Perspectives* 110(Suppl 4): 573–589.
- Galiotte MP, Kohler P, Mussi G, et al. (2008) Assessment of occupational genotoxic risk among Brazilian hairdressers. *The Annals of Occupational Hygiene* 52: 645–651.
- Gupta UP (1982) Formaldehyde in indoor air: sources and toxicity. *Environment International* 8: 349–358.
- Hauksson I, Pontén A, Gruvberger B, et al. (2016) Skin-care products containing low concentrations of formaldehyde detected by the chromotropic acid method cannot be safely used in formaldehyde-allergic patients. *British Journal of Dermatology* 174(2): 371–379.
- Health Canada (2011) Several professional hair smoothing solutions contain excess levels of formaldehyde. Available at: http://www.hc-sc.gc.ca/ahc-asc/media/advisories-avis/_2011/2011_56-eng.php (accessed 13 March 2015).
- Hendrick DJ and Lane DJ (1975) Formalin asthma in hospital staff. *British Medical Journal* 1: 607–608.
- Hendrick DJ and Lane DJ (1977) Occupational formalin asthma. *British Journal of Industrial Medicine* 34: 11–18.
- Hendrick DJ, Rando RJ, Lane DJ, et al. (1982) Formaldehyde asthma: challenge exposure levels and fate after five years. *Journal of Occupational Medicine* 24: 893–897.
- Kilburn KH, Warshaw R, and Thornton JC (1989) Pulmonary function in histology technicians compared with women from Michigan: effects of chronic low dose formaldehyde on a national sample of women. *British Journal of Industrial Medicine* 46: 468–472.
- Kim CW, Song JS, Ahn YS, et al. (2001) Occupational asthma due to formaldehyde. *Yonsei Medical Journal* 42: 440–445.
- Kriebel D, Sama SR, and Cocanour B (1993) Reversible pulmonary responses to formaldehyde. A study of

- clinical anatomy students. *The American Review of Respiratory Disease* 148: 1509–1515.
- Lemiere C, Desjardins A, Cloutier Y, et al. (1995) Occupational asthma due to formaldehyde resin dust with and without reaction to formaldehyde gas. *European Respiratory Journal* 8: 861–865.
- Lin D, Guo Y, Yi J, et al. (2013) Occupational exposure to formaldehyde and genetic damage in the peripheral blood lymphocytes of plywood workers. *Journal of Occupational Health* 55: 284–291.
- Malaka T and Kodama AM (1990) Respiratory health of plywood workers occupationally exposed to formaldehyde. *Archives of Environmental & Occupational Health* 45: 288–294.
- Maneli MH, Smith P, and Khumalo NP (2014) Elevated formaldehyde concentration in “Brazilian keratin type” hair-straightening products: a cross-sectional study. *Journal of the American Academy of Dermatology* 70: 276–280.
- Matubayasi N, Morooka S, Nakahara M, et al. (2007) Chemical equilibrium of formaldehyde and methanediol in hot water: free-energy analysis of the solvent effect. *Journal of Molecular Liquids* 134: 58–63.
- Mazzei JL, Figueiredo EV, da Veiga LJ, et al. (2010) Mutagenic risks induced by homemade hair straightening creams with high formaldehyde content. *Journal of Applied Toxicology* 30: 8–14.
- McCarthy KM, McLaughlin D, Montgomery D, et al. (eds.) (2010) “Keratin-based” hair smoothing products and the presence of formaldehyde. In: *Oregon OSHA COHSU Center for Research in Occupational and Environmental Toxicology (CROET)*. Salem, OR: Oregon OSHA, CROET.
- Nielsen GD, Larsen ST, and Wolkoff P (2013) Recent trend in risk assessment of formaldehyde exposures from indoor air. *Archives of Toxicology* 87: 73–98.
- NIOSH (2009) *A Strategy for Assigning New NIOSH Skin Notations*. National Institute for Occupational Safety and Health. Atlanta, GA: NIOSH 2009–147.
- NIOSH (2011a) Formaldehyde exposures during Brazilian blowout hair smoothing treatment at a hair salon-Ohio. In: Control CFD (ed) *Cincinnati*. Cincinnati, OH: HETA 2011–0014-3147, 1–28.
- NIOSH (2011b) *NIOSH Skin Notation Profiles Formaldehyde/Formalin*. National Institute for Occupational Safety and Health. Cincinnati, OH: NIOSH 2011–145.
- Norback D, Björnsson E, Janson C, et al. (1995) Asthmatic symptoms and volatile organic compounds, formaldehyde, and carbon dioxide in dwellings. *Occupational And Environmental Medicine* 52: 388–395.
- Nordman H, Keskinen H, and Tuppurainen M (1985) Formaldehyde asthma—rare or overlooked? *Journal Allergy Clinical Immunology* 75: 91–99.
- Occupational Safety and Health Administration (OSHA) (2011) Hazard alert: hair smoothing products that could release formaldehyde. Washington, DC: OSHA. Available at: http://www.osha.gov/SLTC/formaldehyde/hazard_alert.html (accessed 28 March 2015).
- Petteff GP, Antunes MV, Carrer C, et al. (2016) Environmental and biological monitoring of occupational formaldehyde exposure resulting from the use of products for hair straightening. *Environmental Science and Pollution Research* 23: 908–917.
- Pierce JS, Abelman A, Spicer LJ, et al. (2011) Characterization of formaldehyde exposure resulting from the use of four professional hair straightening products. *Journal of Occupational and Environmental Hygiene* 8: 686–699.
- Robertson AS, Burge PS, Hedge A, et al. (1985) Comparison of health problems related to work and environmental measurements in two office buildings with different ventilation systems. *British Medical Journal (Clin Res Ed)* 291: 373–376.
- Rumchev KB, Spickett JT, Bulsara MK, et al. (2002) Domestic exposure to formaldehyde significantly increases the risk of asthma in young children. *European Respiratory Journal* 20(2): 403–408.
- Smedje G, Norback D, and Edling C (1997) Asthma among secondary schoolchildren in relation to the school environment. *Clinical and Experimental Allergy* 27: 1270–1278.
- US National Research Council, Committee on Aldehydes, Board on Toxicology and Environmental Health Hazards (1981) *Health Effects of Formaldehyde. Documentation of the Threshold Limit Values and Biological Exposure Indices*. Washington, DC: National Academy Press.
- Winkelman J (2003) *Absorption of Formaldehyde in Water*. Dissertation thesis, University of Groningen, AN.
- Yao Y, Liang W, Zhu L, et al. (2015) Relationship between the concentration of formaldehyde in the air and asthma in children: a meta-analysis. *International Journal of Clinical and Experimental Medicine* 8(6): 8358–8362.