IAQ Incident Involving Insecticide Application and Acute Odorant Release: A Retrospective Review

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Preamble and Summary

Unfortunately, on July 3rd of this year, on the 5th floor of your building, there was a sudden, unexpected IAQ incident that had an effect on occupant health and the ability for you to be productive and feel safe in your workspace. The IAQ incident was unique in that the initiating event appeared routine, but there was clear indication that what occurred was anything but routine. The IAQ incident raised the possibility of exposure to an insecticide, resulted in exposure to an odorant/irritant, and produced occupant health effects including eye, throat and sinus irritation, cough, chest tightness, headache, and lightheadedness. Perhaps most importantly, the IAQ incident resulted in uncertainty about occupant safety, including unanswered questions such as: what happened, what are the health risks, why are some still experiencing symptoms, and why did it take so long to get the facts out?

The following report is a retrospective technical review of this IAQ incident. It presents details that help to describe the event and circumstances leading up to the IAQ incident. It details potential sources for the chemical release and odor, and postulates on the most likely mechanism consistent with the facts. It addresses exposure risks and discusses similarities in health effects reported following other similar incidents.

While hindsight is always 20/20, this is what we now know.

1. The IAQ incident is almost certainly directly linked to the use of a household insecticide and that the use of the insecticide did not involve a spill or use of the product outside its labeled instructions. The product itself had been in the building for over three years and was routinely used without incident. (While the simple fact that the IAQ incident involved this insecticide product may appear self-evident to most, significant effort was expended to establish that no other building-related event was the cause of this IAQ incident.)

2. The contents and concentration of the insecticide product are known and are consistent with the container label. The purchase, source, and custody of the insecticide product were established with confidence.

3. The potential for toxicologically relevant exposure of office occupants to the insecticide product (pyrethrins) is remote. This was deduced from calculation of worst-case air concentrations following theoretical instantaneous release of the product into the air of a confined single office environment. These calculated air concentrations were more than 2 orders of magnitude below the current OSHA permissible exposure limit (PEL), NIOSH REL and ACGIH TLV. It is highly unlikely that health effects reported by 5th floor occupants were related to pyrethrins.

4. It is postulated that the odorants released into the 5th floor office space were degradation by-products of the household insecticide product, a product that itself has very little odor. The insecticide product components, specifically, very low concentrations of pyrethrins (insecticide) and piperonyl butoxide (synergist) [pip•ron•neil butte•oxide] in aqueous solution, are known to degrade on exposure to UV light (sunlight). We also know the insecticide product was stored on or near a credenza located next to a large glass window spandrel with periods of direct exposure to sunlight for over three (3) years. Primary degradation products of piperonyl butoxide retain the piperonyl group and are medium to strong odorants (piperonyl is derived from the manufacturing precursor - sassafras oil). It is further postulated that these odorants accumulated within the insecticide product container forming a residue on the container's internal surfaces. These residues were then re-solubilized when water was added to the product container and it was vigorously shaken. The July 3rd application of approximately 15 mL of this degraded insecticide product is the likely source of odorants that were the hallmark of this IAQ incident.

5. Odorants that are degradation products of piperonyl butoxide are likely irritants. At low air concentrations, irritants can produce the spectrum of health effects reported by some of the 5th floor occupants. These health effects are mediated by both the olfactory receptors (sense of smell) as well as stimulation of trigeminal nerve receptors of the face (eyes, throat, nasal cavity). Occupants may continue to experience symptoms if exposure to the odor or irritant continues or if there is continued uncertainty about the quality of the indoor air.

6. All reasonable effort has been made to remove odorant and insecticide sources from the 5th floor that are related to this incident. Special odor adsorbent filters remain on the main air handler units. Building ventilation and other aspects of indoor air quality have been, and will be, optimized both for the 5th floor as a whole, and on a case-by-case individual basis, with the goal of achieving occupant satisfaction with their indoor environment. This process will take some time to be fully effective.

7. There is currently no toxicological-based rational for avoidance of the 5th floor although continued experience of health effects by some occupants may preclude satisfactory re-introduction for these occupants.

Table of Contents:

Statement of Work

Conduct a retrospective technical review of available information and data related to an indoor air/environmental quality incident that occurred on the 5th floor of an urban "Class A" office building.

Produce a report describing:

1) Details of the initiating event,
2) Details of the indoor air quality incident including occupant reported health effects,
3) Insecticide products, agents, chemicals and odorants involved or released, and
4) Conclusions with recommendations for follow-up as appropriate.

Methods

Review all available written accounts and correspondence related to the IAQ incident and initiating events that may be relevant and necessary to construct a complete description of the initiating event and IAQ incident.

Conduct interviews with key persons involved in the initiating event and IAQ incident as necessary to construct a complete description of the initiating event and IAQ incident.

Facilitate consultations with subject matter experts as necessary to identify or postulate the circumstances, causes and effects of the IAQ incident.

Goal and Objectives

Provide a summary of event information, potential incident related agent/chemical sources, and exposure and risk assessment to be used for communication with building occupants.

Provide IAQ incident analysis and follow-up recommendations to assist in planning that is intended to promote and maintain acceptable IAQ at the site.

Provide reporting and communication to assist medical providers who treat patients following the IAQ incident.

Limitations

The review is commissioned approximately 5 weeks post-event. Odors associated with the incident are no longer reported by building occupants. The insecticide product and the plant that was treated with the insecticide product are no longer available for examination or testing. Prior to this review, materials such as carpets and ceiling tiles located in the insecticide over-spray zone, as well as building surfaces on the 5th floor including windows, carpets and furnishings, have been cleaned to remove potential residues of the insecticide. For these and other reasons, exposure assessment shall be estimated using best available data and/or information, including product labeled ingredients and concentrations.

1. Introduction and Background

The following report presents a retrospective technical review of an indoor air quality (IAQ) incident, a review that was initiated 4 weeks after the triggering event for the incident. The analysis and conclusions presented are products of a process that included interviews with building occupants to clarify their reported circumstances and personal observations and a medical symptom survey intended to document physical experiences and health effects. It is important to understand that this review benefited from having a 2-week period to gather and analyze information, solicit input from several subject mater experts, and work through various hypotheses for the source and cause of this incident. The overall goal of the study was to facilitate a path toward recovery following this IAQ incident.

While this report does not present a complete picture or analysis of the dynamic of the "real-time" response to the incident, the report does present several features of the events that had an impact on that short-term response. For example, most occupants and responders had little doubt that the source of the IAQ incident was a bottle of common household "plant" insecticide. Furthermore, the product was so commonly used in everyday circumstances that the perceived health risk by the occupants and responders was very low. Quite naturally the action of removing the bottle of household insecticide, and the plant on which it was applied, made perfect sense. It was expected that this action would resolve the "problem". In fact, once the product and plant were removed from the space, and the odor began to subside, it was generally reported that the indoor environment was returning to normal. It was surprising when there was a following wave of concern as the odor persisted for more than a week and initial reports of delayed adverse health effects were received.

The odor was the predominant confounding feature this IAQ incident and it had a clear impact on the dynamics of the short-term and long-term response. That is, the presence of the "unusual" odor was both unexpected and pungent, and it appeared to be emanating from a common "odorless" insecticide product. The odor could not be described based on previous experiences of the 5th floor occupant's or reconciled with the general assessment that the product was "safe". As a result, in the days and weeks following the triggering event, a concern that the odor warned of an exposure to an insecticide with an unknown level health risk began to evolve. This evolving concern was offset against a gradual reduction and almost resolution of the odor experience and general re-occupancy of the space without physical effects for some of the staff. Despite many indications that the 5th floor indoor environment was returning to an acceptable quality, health effects lingered for some occupants; some occupants experienced discomfort when occupying at least some areas on the 5th floor, and the entire experience remained generally disconcerting.

With the goal of advancing the process toward full recovery from this IAQ incident, this report presents all available information describing the initiating events and the progression of the incident. It provides background on the chemistry, formulation, labeled use, and toxicology of the insecticide product and offers postulated scenarios for the source of the odor. The report documents the reported health effects and discusses the role of the olfactory sense and chemo-receptor/irritant response associated facial sensation via trigeminal innervation. Although this report describes the actions taken to date to resolve the IAQ incident and to protect the occupants of the 5th floor, the report does not attempt to present an in-depth critique of these actions. Finally, the report presents additional measures that can be taken to blend the final IAQ incident response with general building indoor air quality management and looks ahead with suggestions for areas of focus as discussions move toward means and methods to limit the potential for a repeat of this IAQ incident.

2. Event Description

On the morning of July 3, 2014, a routine household insecticide application was performed by a tenant employee to treat an indoor plant located in an office on the 5th floor of a commercial, Class-A, urban office building. Nearby building occupants subsequently identified this event as the source of an IAQ incident impacting a significant portion of the building's 5th floor.

2.1. Background and Circumstances

A perimeter corner office space measuring approximately 12' x 18' was occupied by a single person. For approximately 3.5 years a plant, which was given to that person as a gift, was positioned in this office[i]. The plant, a Ponytail Palm (*Beaucarnea recurvate*), hosted colonies of mealybugs (*Maconellicoccus hirsutus*) for most of the previous 3.5-years. At the same time the plant was placed in the office a single bottle of household insecticide was purchased to control the mealybugs. This insecticide product was identified as "Garden Safe® Brand Houseplant & Garden Insect Killer"[ii]. The product was contained in a 750 mL bottle equipped with a manual "trigger" spraying apparatus. The bottle of insecticide was stored near the plant in the office where it was exposed to sunlight. Approximately once every 4-6 weeks the insecticide was applied to the plant and these treatments were effective in controlling the mealybugs. Use of this insecticide product continued in the office area without incident for approximately 3.5 years, prior to July 3, 2014.

On July 3, 2014 the office occupant began the routine process of applying the insecticide to the ponytail palm. At this time the bottle of insecticide was reported to be approximately 20% full, containing approximately 150 mL of liquid insecticide product. This remaining amount of insecticide (150 mL) is consistent with a consumption rate of 40 applications of 15 mL each over 3.5 years. Initially this last application began without incident and was estimated to involve 1-3 sprays. However, it was found that the quantity of liquid insecticide remaining in the product spray bottle was too low to allow the bottle to be tilted and the internal straw that feeds the sprayer to remain in contact with the liquid so that the sprayer would remain primed for application. For this reason the office occupant walked to a nearby office pantry and dispensed approximately between 150 - 300 mL of tap water from the pantry sink into the bottle. As the employee walked back to the office to continue the spray application, the bottle was vigorously shaken to mix the tap water with the remaining contents of the bottle. Nothing out of the ordinary was noticed when adding the water until the insecticide application was restarted and then, within a short period of time, the

occupant detected an odor. At that moment, the spray application was discontinued.

2.2. Analysis/Conclusions

Based on available information, including anecdotal reports, there is no indication that the insecticide product was spilled, released, or otherwise used in a manner inconsistent with labeled instructions. It is our opinion that dilution of this insecticide product with uncontaminated potable water is not outside the label instructions for this product. Furthermore, it is our opinion that dilution of this insecticide product with uncontaminated potable water is not considered "mixing" as addressed on the product label. No deleterious effect would be anticipated following dilution of this insecticide product with uncontaminated domestic potable water.

3. Incident Description

During the post-dilution application of the insecticide product, and immediately after, the occupant making the application detected a significant odor and recognized the condition as abnormal. The odor quickly spread inside the corner office and into the hallway triggering an IAQ incident on the 5th floor.

3.1. Odor description and movement

A short time after the insecticide application, occupants located near the corner office detected an odor. In the days and weeks that followed, the majority of occupants on the 5th floor also reported an odor. Description of the odor varied, including a burnt smell, but the most remarkable feature of the odor was the difficulty most occupants had in associating the type of odor with any of their previous experiences.

The odor was initially reported concentrated at the point of the insecticide application however the odor soon spread throughout the north end of the space as the fire stairwell doors were opened in an effort to exhaust the odor from the space. Subsequently the ponytail palm was removed from the office as was the insecticide bottle and this coincided with reports that the odor was moving away from the 5th floor, eventually being detected in an area where the plant was positioned on a building's loading dock before disposal. In the days following the IAQ incident, a few persons with offices on the south end of the 5th floor, some distance from the insecticide application, also reported detecting an odor.

3.2. Initial Response Actions

The combination of pungent odor, uncertainty about the nature and source of the odor, and health symptoms reported by some building occupants resulted in relocation of most staff away from the source of the odor within hours of the IAQ incident. In some cases, occupants relocated to other buildings or worked from home. In other cases persons not on the 5th floor at the time of the July 3rd event reported an odor in their workspace when they returned the following week. In some of these cases these 5th floor occupants elected to relocate or work remotely.

In the days and weeks following the IAQ incident, several actions were taken to reduce the frequency and intensity of the reported odor and to reduce any potential for exposure to the insecticide. These actions included:

1. Removing potential odorant sources, including the container of insecticide and the treated plant,
2. Removing carpet and ceiling tiles in the area of insecticide application,
3. Carpet cleaning approximately 25% of the 5th floor,
4. Cleaning wall, window, and furniture surfaces on the 5th floor,
5. Increasing the 5th floor ventilation rate (that is, increasing the indoor/outdoor air changes), and
6. Installing supplemental charcoal filters on the main 5th floor air handler unit.

3.3. Building Inspection for Alternative Odor Sources

Essentially all occupants on the 5th floor associated the indoor application of the insecticide product with the sudden release of an odorant into their workspace. These reports are paradoxical, as use of this insecticide product, even when accompanied with reports of adverse health effects, has never included a report of odor. Obviously one solution to this paradox would be that there was a simultaneous but separate odorant release unrelated to the insecticide application. This possibility was investigated.

As noted, the initial odor was focused near the northeast corner of the 5th floor, essentially within the office where the insecticide product was applied to a houseplant. Careful examination of this office area did not identify any other obvious odorant source other than the insecticide product used in this office. Furthermore, examination of building ventilation system components serving the 5th floor, including the main air handling unit, the air distribution boxes mounted above the ceiling tiles (VAV boxes and fan-powered terminal units), and the open return air plenum, did not identify any other source for the odor. Building

maintenance conditions were also considered for possible sources of odor, including: failure or overheating of motors, belts, gears, electrical equipment and/or wiring. No suspect condition was identified. Odor sources outside the building were also considered but the outdoor air supplied to the 5th floor also supplies the remainder of the building where no odor was detected (except as explained by opening of the stairwell doors and movement of the treated plant off the 5th floor). Based on these building inspections and other corroborating details, it was concluded that the odorant involved in this IAQ incident was indeed directly related to the insecticide product. The paradox remains unresolved, as the insecticide product's ingredients do not emit a significant odor.

3.4. Reported Adverse Health Effects

A medical survey of symptoms and health effects was conducted and reported separately. (Reference: Memorandum dated 13 August 2014. "*Medical Interviews for U.S. EPA Workers Exposed to a Pesticide at the Potomac Yard North- 2733 Crystal Drive, Arlington, VA*" Christopher S. Holland, MD, MPH, U.S. Public Health Service). From this medical report, the following health effects are noted as reported:

1. Red, sore, watery, burning eyes.
2. Ear burning, face burning, sinus congestion,
3. Sore, burning, tight throat, raspy voice, hoarse voice,
4. Cough,
5. Headache,
6. Chest pain, tightness in chest, shortness of breath, wheezing,
7. Skin rash, itching, blisters,
8. Lightheadedness, disorientation, imbalanced, dizzy, foggy headed, and
9. Nausea.

Following the IAQ incident, no emergency medical treatment was reported for any occupant. Approximately 25% of 5th floor occupants interviewed have seen their personal physician. Two occupants have not returned to work pending medical clearance.

The most predominant of these reported symptoms can share a common etiology; stimulation of the olfactory receptors located in the nasal epithelium (1st cranial nerve) and stimulation of facial sensory receptors associated with the nasal cavity, ears, throat, eyes, and facial skin (5th cranial nerve or trigeminal nerve). These nerve receptors play an integrate role in the expression of symptoms following exposure to odorants and irritant chemicals.

A full discussion of the role olfactory sense and trigeminal facial receptor modulation of human response following exposure to odorant/irritant chemicals is beyond the scope of this report. A list of reference materials is nevertheless provided if additional background on the subject is desired.

1. Health Effects of Indoor Odorants. James E. Cone, Dennis Shusterman. Environmental Health Perspectives. Vol. 95, pp. 53-59, 1991
2. Indoor Air Chemistry – Olfaction and Sensory Irritation – An Overview. Peder Wolkoff. Geophysical Research Abstracts, Vol. 7, 09215, 2005.
3. Odor-associated Health Complaints: Competing Explanatory Models. Dennis Shusterman. Chem Senses, 26, 339-343, 2001.
4. Olfaction. Update No. 5. John C. Leffingwell, Ph.D. Leffingwell Reports, Vol. 2 (No. 1), May, 2002.
5. Organic compounds in office environments – sensory irritation, odor, measurements and the role of reactive chemistry. P. Wolkoff, C. K. Wilkins,P. A. Clausen, G. D. Nielsen. Indoor Air 2005
6. The "Gray Line" Between Odor Nuisance and Health Effects. Michael A. McGinley, Proceedings of Air and Waste Management Association. 92nd Annual Meeting and Exhibition. St. Louis, Mo: 20-24 June 1999.

Other factors can play an important role in the complex timing and expression of health effects following an odorant/irritant exposure incident. For example, it is common for trigeminal nerve mediated responses to be delayed; a delay that may be related to toxicological effects impacting the receptor proteins. In addition, the sense of smell (olfactory) is closely related to an organism's preservation and defense mechanisms. The result is a memory effect or sensitization to odor response that produces interesting interplay between physiological and psychological effects.

A full discussion of symptomology features related to human response to odorants/irritants is beyond the scope of this report. A list of reference materials is nevertheless provided if additional background on the subject is desired.

1. The influence of cognitive bias on the perceived odor, irritation and health symptoms from chemical exposure. Dalton P, Wysocki CJ, Brody MJ, Lawley HJ., International archives of occupational and environmental health. 69:6 1997 pg 407-17.
2. Effect of Acute Exposure to a Complex Fragrance on Lexical Decision Performance. Daniel E. Gaygen. Alan Hedge. Chem. Senses 34: 85–91, 2009.
3. The influence of health-risk perception and distress on reactions to low-level chemical exposure. Andersson L, Claeson AS, Ledin L, Wisting F, Nordin S., Front Psychol. 2013 Nov 5;4:816.

3.5. IAQ Incident: Current Status

At the outset of this technical review, occupants of the 5th floor rarely reported detectable odor. Nevertheless, some occupants indicate that the odor remains

a health concern and a nuisance. Interviews conducted by an occupational physician suggest the residual concern is related to uncertainty about linkage between the odor and exposure to the applied insecticide.

The building ventilation systems have been returned to standard operational settings, carpet and ceiling tiles that were removed have been replaced, and the general work environment has returned to normal for most occupants. Communications based on findings from this technical review are scheduled shortly after release of this report.

3.6. Analysis/Conclusions

The IAQ incident involves two components; (1) the potential release of, and occupant exposure to, a common household insecticide and (2) the release of an odorant with an effect that persisted in the indoor environment for several weeks. Both components of this IAQ incident are related to use of a common insecticide product. The reported health effects associated with the IAQ incident are consistent with exposure to an odorant/irritant chemical. Response actions including removal of insecticide product sources and optimization of mechanical ventilation of the space improved the quality of the indoor environment and occupant satisfaction with the indoor environment. The odor related to the IAQ incident is no longer detected with any consistency and most occupants have returned to work on the 5th floor.

4. Insecticide Product Ingredients

The “Garden Safe® Brand Houseplant & Garden Insect Killer” product, and closely related products manufactured and sold by various entities under many different trade names, contains a very low concentration of active insecticide and synergist, ingredients noted for their inherently low mammalian toxicity and limited environmental impact. The active insecticide and synergist found in these products are approved for use on foodstuffs, with food consumption being the primary source for exposure of the general population to this insecticide.

4.1. Insecticide product composition

“Garden Safe® Brand Houseplant & Garden Insect Killer” contains two reported ingredients, Pyrethrins (I) (this insecticide accounts for 0.02% of the total product) and Piperonyl Butoxide (referred to as “PBO”, this non-insecticide synergist accounts for 0.2% of the total product). These two product components are dissolved in water (aqueous solution) and together represent the entire reported product composition (100%).

Unreported components typical for pyrethrin-based insecticide products include unreacted synthesis precursor and various stabilizing agents. Safrole (purified from sassafras oil) is the predominant unreacted precursor in insecticide formulations similar to "Garden Safe® Brand Houseplant & Garden Insect Killer"[1] (Reference: WHO Specifications and Evaluations for Public Health Pesticides - Piperonyl Butoxide). Safrole content is specified at less that 0.1% of PBO raw product, and the concentration in a final insecticide formulation would be less than 0.0002%.

Historically, products such as "Garden Safe® Brand Houseplant & Garden Insect Killer" would contain trace amounts of antioxidants and ultra-violet light absorbers (e.g. pyrocatechol, pyrogallol, hydroquinone, benzene-320-napthol). Currently, the best information suggests that pyrethrin-based insecticide formulations no longer contain stabilizing agents, in part because of cost and in part because they have been determined to be ineffective.

A single 750 mL container of "Garden Safe® Brand Houseplant & Garden Insect Killer" contains a total of 150 mg of pyrethrins and 1.5 g of PBO. At the time of the application of this insecticide on July 3rd, it is estimated that 30 mg of pyrethrins and 300 mg of PBO remained in the product container. It is estimated that 15 mL of product was dispensed during each application on the office plant; an application that was repeated 40 times over the 3.5 year period the product was present in the office. It is estimated that each application event dispensed 3 mg of pyrethrins and 30 mg of PBO. Dispensed pyrethrins degrade via photo-hydrolysis with a half-life of approximately 4 days. It is estimated that the pyrethrins dispensed during each application to the plant on the 5th floor will degrade within 1-3 months.

4.2. Pyrethrins toxicology

Pyrethrins (I) are the insecticidal component of the "Garden Safe® Brand Houseplant & Garden Insect Killer". These are a naturally occurring group of three chemically related esters (esters of chrysanthemic acid), each of which is insecticidally active.

Pyrethrins can be absorbed across the gastrointestinal tract and pulmonary membranes, but only slightly across intact skin. They are quickly hydrolyzed to

[1] Some pathways for the synthesis of PBO do not use safrol as a precursor. At this time we have not be able to establish which pathway was used for the synthesis of PBO used for the Garden Safe® Brand.

inert products by mammalian liver enzymes. This rapid degradation and poor bioavailability results in their relatively low mammalian toxicity.

Pyrethrins are one of the most common household insecticides in the United States, in large part as a result of their low mammalian toxicity, low environmental persistence, and slow resistance development in pests. Pyrethrins-containing dusts are used to control agricultural insects and are approved for use on foodstuffs. Pyrethrins are also the active ingredient in lice control preparations including shampoos and lotions. Pyrethrins are the most common ingredient in household "bug sprays" and bombs.

> A full discussion of the toxicology of pyrethrins is beyond the scope of this report. A list of reference materials is provided if additional background on the subject is desired.
>
> 1. Recognition and Management of Pesticide Poisonings - Sixth Edition, 2013. James R. Roberts, J. Routt Reigart, M.D. *Medical University of South Carolina.*
> 2. Public Health Statement - Pyrethrins and Pyrethroids. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.
> 3. Pyrethrin and Pyrethroid Illnesses in the Pacific Northwest: A Five-Year Review. Public Health Reports / January–February 2009 / Volume 124. P 149.
> 4. Environmental Fate of Pyrethrins. Amrith S. Gunasekara. Environmental Monitoring Branch Department of Pesticide Regulation. November 2004 (Revised 2005)

4.3. Odor and piperonyl butoxide decomposition

Pyrethrins, PBO and the "Garden Safe® Brand Houseplant & Garden Insect Killer" product do not exhibit an odor, and reports of odors following use of this product on July 3rd remain an unresolved paradox. Without chemical characterization of the offending insecticide product, the solution to this paradox can only be speculated.

One plausible explanation for the IAQ incident odor is decomposition of PBO. Decomposition of PBO is likely to produce a series of chemical homologues that share similar structural features with known odorants. The question remains, what would explain the sudden production of an odorant from a product that was previously stable and used on multiple occasions without odor incident?

Increased degradation (hydrolysis) reaction rate of PBO is linked to both UV light exposure and/or exposure to oxidizing agents. Thus, two potential explanations for the production of odorants from PBO can be postulated. The first is exposure of the insecticide product to direct sunlight (and perhaps heat) prior to the events of July 3rd. This scenario is plausible based on the floor-to-ceiling glass window wall forming one side of the office where the plant is located and where the insecticide product was stored. The second is the

presence of oxidizing agents (e.g. nitrite, other corrosion control agents, chlorine, or low (<5) or high (> 9) pH) in the building's domestic water supply. Water conditions related to this scenario can be evaluated by testing of the building's domestic water supply at the dispensing tap on the 5th floor (results from testing were negative and will be presented under a following "Water testing" header).

> A full discussion of the chemistry of piperonyl butoxide is beyond the scope of this report. A list of reference materials is provided if additional background on the subject is desired.
>
> 1. The UNITED STATES PATENT OFFICE. 2,485,680 DIHYDROSAFROL DERIVATIVES. Herman Wachs, Brooklyn, N. Y., Application April 1,1946, Serial No. 658,872
> 2. Piperonyl Butoxide – The Insecticide Synergist. Ed. D Glynne Jones. Academic Press.1998

4.4. Exposure assessment

Notwithstanding the inherently low mammalian toxicity of the insecticide found in the product related to this IAQ incident, there have been numerous reports of adverse health effects following exposure to pyrethrins. These reports rarely involve products similar to the "Garden Safe® Brand Houseplant & Garden Insect Killer" but are instead related to products that contain higher concentrations of pyrethrins and that are applied directly to skin and hair, or dispensed as saturation fogs. A recently completed US EPA review of poison control reports of pyrethrin-related incidents concluded that pyrethrins remain safe for domestic use.

Inhalation

The current concentration of pyrethrins in the building indoor air does not reflect the conditions on July 3rd. Nevertheless, it is possible to calculate a maximum theoretical concentration of pyrethrins in the indoor air immediately following the July 3rd insecticide application. For example, following an application of 15 mL of the "Garden Safe® Brand Houseplant & Garden Insect Killer", and assuming an instantaneous vaporization and distribution of all pyrethrins contained in this application into the confined office indoor air (12' x 18' x 8' office dimensions), the maximum theoretical pyrethrins air concentration would be 50 micrograms/m^3 (rounding to one significant figure). For comparison, the current OSHA PEL and ACGIH TLV for pyrethrins is 5,000 micrograms/m^3 as an 8-hour time-weighted average. Of course this estimation of the pyrethrins air concentration is unrealistically conservative as it does not account for the low pyrethrin vapor pressure, the dilution of the indoor air on the 5th floor, or the

removal of pyrethrins by indoor/outdoor air changes. Based on this estimated air concentration, it is unlikely that the July 3rd insecticide application would have produced toxicologically relevant exposures.

Dermal contact

Dermal contact with pyrethrins is common and several pyrethrin-based shampoos; lotions and skin sprays are approved for human use. These products contain pyrethrins at 10-15 times the concentration found in "Garden Safe® Brand Houseplant & Garden Insect Killer". The most common side effect following dermal contact is skin irritation not present before use.

The application of "Houseplant & Garden Insect Killer" is designed to produce insecticidal residues on surfaces, but without significant aerosolization of the product. In the case of the insecticide application in the 5th floor office, the pyrethrins were dispensed directly onto plant leaf surfaces using a low velocity mechanical sprayer. This sprayer produces large water droplets that are not suspended in air (aerosolized) but fallout over a short distance from the spray nozzle orifice. The net result is control over the placement of pyrethrin residues onto the intended surface (the plant).

Following an IAQ incident involving an insecticide application there is concern that surface residues pose an unacceptable risk for exposure. For several reasons, including the short half-life of pyrethrins, the lack of an effective transport mechanism that would contaminate office areas beyond the boundaries of the area of application, and the small amount of insecticide present during the application, the potential for dermal exposure is very low.

Furthermore, developing a reliable estimate of pyrethrins dermal exposure is difficult because of the experimental design requirements necessary to produce a valid data set, the lack of health-based interpretive criteria, and the presence of confounding sources of pyrethrins in the building.

4.5. Water testing

Operating under a "belts and suspenders" approach, a plan was developed and executed to test the building's domestic water at one discharge tap in one galley on the 5th floor. This "range finding" experiment was designed to explore a hypothesis that oxidizing agents, or an abnormal pH, could have played a role in the hydrolysis of PBO and the production of odorant by-products. The water sample collection and testing is complete and all measured parameters were

within the expected range and there is no suggestion that a condition of the tap water resulted in rapid hydrolysis of PBO and production of odorants.

4.6. Analysis/Conclusions

The IAQ incident initially focused concern on the possible release of pyrethrins insecticide into the environment. However, the hallmark of the July 3rd IAQ incident is the presence of a pungent odor, an odor that is not consistent with the release of pyrethrin-based insecticides or use of the commercial product ("Garden Safe® Brand Houseplant & Garden Insect Killer"), both of which are generally considered odorless.

The synergist piperonyl butoxide may degrade to produce odorants. These by-products would be the most likely source for the odors reported during this IAQ incident and would be consistent with irritant-related health effects reported by many of the occupants on the 5th floor. Unfortunately is not possible to identify the exact odorants involved in this IAQ incident and not possible to confirm the hydrolysis reaction kinetics that would produce these odorants.

The potential for building occupants to be exposed to a toxicologically relevant concentration of pyrethrins during the IAQ incident is remote. The most conservative estimate of instantaneous peak pyrethrin air concentration produced during the IAQ incident is two orders of magnitude below the current OSHA PEL. Reasonably accounting for the low vapor pressure for pyrethrins and the rapid dilution and removal of pyrethrins from the indoor air over a short period by building mechanical systems, actual pyrethrins air concentrations were likely very low and below the detection limits of OSHA analytical methods.

5. Conclusions and Recommendations

5.1. Conclusions (as presented in the Preamble and Summary)

5.1.1. The IAQ incident is almost certainly directly linked to the use of a household insecticide and that the use of the insecticide did not involve a spill or use of the product outside its labeled instructions. The product itself had been in the building for over three years and was routinely used without incident. (While the simple fact that the IAQ incident involved this insecticide product may appear self-evident to most, significant effort was expended to establish that no other building-related event was the cause of this IAQ incident.)

5.1.2. The contents and concentration of the insecticide product are known and are consistent with the container label. The purchase, source, and custody of the insecticide product were established with confidence.

5.1.3. The potential for toxicologically relevant exposure of office occupants to the insecticide product (pyrethrins) is remote. This was deduced from calculation of worst-case air concentrations following theoretical instantaneous release of the product into the air of a confined single office environment. These calculated air concentrations were more than 2 orders of magnitude below the current OSHA permissible exposure limit (PEL), NIOSH REL and ACGIH TLV. It is highly unlikely that health effects reported by 5th floor occupants were related to pyrethrins.

5.1.4. It is postulated that the odorants released into the 5th floor office space were degradation by-products of the household insecticide product, a product that itself has very little odor. The insecticide product components, specifically, very low concentrations of pyrethrins (insecticide) and piperonyl butoxide (synergist) [pip•ron•neil butte•oxide] in aqueous solution, are known to degrade on exposure to UV light (sunlight). We also know the insecticide product was stored on or near a credenza located next to a large glass window spandrel with periods of direct exposure to sunlight for over three (3) years. Primary degradation products of piperonyl butoxide retain the piperonyl group and are medium to strong odorants (piperonyl is derived from the manufacturing precursor - sassafras oil). It is further postulated that these odorants accumulated within the insecticide product container forming a residue on the container's internal surfaces. These residues were then re-solubilized when water was added to the product container and it was vigorously shaken. The July 3rd application of approximately 15 mL of this degraded insecticide product is the likely source of odorants that were the hallmark of this IAQ incident.

5.1.5. Odorants that are degradation products of piperonyl butoxide are likely irritants. At low air concentrations, irritants can produce the spectrum of health effects reported by some of the 5th floor occupants. These health effects are mediated by both the olfactory receptors (sense of smell) as well as stimulation of trigeminal nerve receptors of the face (eyes, throat, nasal cavity). Occupants may continue to experience symptoms if exposure to the odor or irritant continues or if there is continued uncertainty about the quality of the indoor air.

5.1.6. All reasonable effort has been made to remove odorant and insecticide sources from the 5th floor that are related to this incident. Special odor adsorbent filters remain on the main air handler units. Building ventilation and other aspects of indoor air quality have been, and will be, optimized both for the 5th floor as a whole, and on a case-by-case individual basis, with the goal of achieving occupant satisfaction with their indoor environment. This process will take some time to be fully effective.

5.1.7. There is currently no toxicological-based rational for avoidance of the 5th floor although continued experience of health effects by some occupants may preclude satisfactory re-introduction for these occupants.

5.2. Recommendations

5.2.1. Care of indoor plants

Building occupants frequently place indoor potted plants at or near their work area. Responsibility and protocols for the care of these personal plants may not be clearly established. At a minimum, informal expectations for the maintenance of a plant's condition, and criteria for removing a plant when it is either unhealthy or hosting insect populations, should be developed. When plants require insecticide treatment to maintain their health, the benefit of including such insecticide applications into the building's Integrated Pest Management Plan should be considered.

5.2.2. Responding to a sudden release of odorant in a office environment

The sudden, unexpected, release of an odorant is one hallmark of this IAQ incident. The building ventilation system design limits the effective use of building systems to rapidly remove odorants (or any other problematic indoor air contaminant) by direct building air exhaust. The building engineering staff should be consulted to determine how best to configure building exhaust systems to rapidly purge contaminated air from an occupied floor.

5.2.3. Ventilation air distribution and mixing, odor sources, and acceptable indoor air quality

During this IAQ incident review, several occupants of the 5th floor commented on previous nuisance odors in the office space. These odors included scented materials introduced to the indoor space by occupants

and construction related odors such as can occur following drywall installation and application of wall finishes. There is value in reviewing the odor control strategies for the floor, including discussion of limiting and removing odor sources, optimizing ventilation air mixing and distribution, with confirmation of the effectiveness of HVAC system design. The value of direct measurement of indoor air mixing, distribution and ventilation rate should be discussed with IAQ experts. Guidelines for performing ad hoc alterations to supply and return airflow patterns should be established.

Endnotes

[i] Photo of ponytail palm positioned near the office window.

[ii] A scan of the insecticide bottle showing the label and ingredients.