



Respiratory disease associated with occupational inhalation to hop (*Humulus lupulus*) during harvest and processing

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ABSTRACT

Background: There is little published evidence for occupational respiratory disease caused by hop dust inhalation. In the United States, hops are commercially produced in the Pacific Northwest region.

Objective: To describe occupational respiratory disease in hop workers.

Methods: Washington State workers' compensation claims filed by hop workers for respiratory disease were systematically identified and reviewed. Incidence rates of respiratory disease in hop workers were compared with rates in field vegetable crop farm workers.

Results: Fifty-seven cases of respiratory disease associated with hop dust inhalation were reported from 1995 to 2011. Most cases (61%) were diagnosed by the attending health care practitioner as having work-related asthma. Seven percent of cases were diagnosed as chronic obstructive pulmonary disease, and the remaining cases were diagnosed as allergic respiratory disorders (eg, allergic rhinitis) or asthma-associated symptoms (eg, dyspnea). Cases were associated with hop harvesting, secondary hop processing, and indirect exposure. The incidence rate of respiratory disease in hop workers was 15 cases per 10,000 full-time workers, which was 30 times greater than the incidence rate for field vegetable crop workers. A strong temporal association between hop dust exposure and respiratory symptoms and a clear association between an increase in hop dust concentrations and the clinical onset of symptoms were apparent in 3 cases.

Conclusion: Occupational exposure to hop dust is associated with respiratory disease. Respiratory disease rates were higher in hop workers than in a comparison group of agricultural workers. Additional research is needed before hop dust can be confirmed as a causative agent for occupational asthma.

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Introduction

Respiratory disease and airway irritation from exposure to the hop plant, *Humulus lupulus*, are reported each year to Washington State's workers' compensation system. Although regional health care practitioners recognize hop dust exposure to be associated with respiratory symptoms, there is little evidence in the published literature of hop dust causing occupational respiratory disease, such as occupational asthma. Newmark¹ reported a sentinel case of hop allergy in 1975 for a brewery chemist having respiratory symptoms of wheeze and shortness of breath associated with hop exposure and a positive scratch test result to hop extract. A 2013 occupational asthma literature review by Baur and Baekehe² found

no additional evidence of hop-induced asthma cases beyond the sentinel case published by Newmark.² Occupational asthma occurred in 2 of 97 Croatian workers (2%) exposed to a mixture of hop, barley, corn, brewer's yeast, environmental mold, and mildew in a brewery setting.³

Hops are the female flowers or seed cones of the hop plant and are harvested principally for beer brewing. The United States is the world's second largest hop-producing country, with large-scale commercial production occurring in the Pacific Northwest states of Washington, Oregon, and Idaho.^{4,5} Smaller scale hop production, in support of regional craft brewing, occurs throughout the continental United States.

The cases presented here are from Washington State family-operated hop farms that average 450 acres in size and are typically diversified with tree fruit, mint, grapes, and other crops. There are several job titles and processes associated with hop production discussed in this article. In the hop field, trellised hop vines are manually or mechanically cut by laborers and loaded onto truck trailers pulled by trucks driven by truck drivers. A centralized enclosed or semienclosed harvest facility with one or more truck bays is the site of hop processing. Hop hangers work from the trailer bed to hang 30-ft hop vines from a ceiling-mounted conveyor that

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feeds the picking machine. The picking machine, followed by a system of conveyors and dribble belts, separates the hop cone from the vine and leaves. Fallen hops are reclaimed by workers with brooms known as hop sweepers and returned into the processing system. Cleaned cones are conveyed to a walk-in drying kiln elevated over heaters and blowers, where kiln operators ensure ideal hop moisture content. Once dried, hop cones are compressed into bales, which may be secondarily packaged into pellets or extract. Pellet plant production essentially involves hop bale breaking, plant waste removal, and milling of the hops into powder, which is blended extensively before being compressed into pellets. Hop extraction can be achieved several ways, including a process that uses carbon dioxide at low temperature to preserve the flavor, aroma, and bittering characteristics of the hops.

The purpose of this article is to provide evidence in support of a causal relationship between hop dust exposure and subsequent respiratory disease. We characterize workers' compensation cases in the hop industry for respiratory disease by medical diagnosis, disease incidence rate, and exposure attributes, such as task and length of employment. We provide detailed information on 3 cases that supports the relationship between hop dust exposure and subsequent respiratory disease.

Methods

Respiratory disease induced by exposure to hop was initially recognized through our state's occupational asthma surveillance system. In Washington State, suspected or confirmed cases of occupational asthma must be reported by health care practitioners and hospitals to the Washington State Department of Labor and Industries (L&I). The surveillance system's primary data source is L&I's industrial insurance workers' compensation system, hereafter referred to as workers' compensation data. To understand the magnitude of disease caused by hop dust inhalation, the workers' compensation data were also reviewed for respiratory cases that would not have been captured by the surveillance system (eg, respiratory cases other than asthma). Using both the asthma surveillance system and workers' compensation data directly, we identified a total of 57 hop-induced respiratory cases for the period 1995 through 2011.

Asthma Surveillance System

Fourteen cases of hop-induced asthma were initially identified through the asthma surveillance system, which was initiated in 2001 and has been previously described.⁵ Briefly, workers' compensation claims are downloaded monthly from the workers' compensation data into the asthma surveillance system based on a text search for *asthma* (or its misspelling) on the Report of Industrial Injury or Occupational Disease (RIIOD) form. The RIIOD initiates a claim and is completed by the injured worker, the employer, and the health care practitioner. Potential asthma patients are interviewed by telephone to obtain the suspected agent causing the asthma and their medical history. Agents are coded using the Association of Occupational and Environmental Clinics coding system, which has classified hops as an asthmagen.⁷ The asthma surveillance protocols have been approved by the Washington State Institutional Review Board.

Washington's Workers' Compensation System

Forty-three additional cases of hop-induced respiratory disease were identified through the workers' compensation system, which has been previously described.⁶ Briefly, workers' compensation insurance is mandated for all nonfederal employers in Washington State through the State Fund unless they are covered by an alternative workers' compensation insurance program or are self-employed. The State Fund provides coverage for approximately

97.7% (170,000) of all employers mandated to have state workers compensation coverage and approximately two-thirds (1.9 million workers) of the state workforce. The remaining 450 employers self-insure for workers' compensation and employ the remaining one-third of the nonfederal workers.

We selected respiratory cases for review based on industry, the nature of injury, the body part affected, and an injury report date occurring between 1995 and 2011. Industry selection was based on Washington's insurance risk classification system.⁸ The risk classification system groups establishments based on the type of work performed and insurance risk. Hop industry was defined to include all 5 of the risk classifications that had been assigned to the 14 asthma cases initially identified through the asthma surveillance system. The 5 risk classifications were hop and mint farms; hop pellet manufacturing; extract manufacturing, including distillation of essential oils; grain milling, flour mills, and feed mills; and salt, borax, or potash producing or refining.⁸ Regarding the nature of injury, injuries coded as traumatic injury and disorders and musculoskeletal system and connective tissue diseases and disorders were excluded by using the Occupational Injury and Illness Classification System Nature of Injury or Illness codes of 0 and 17, respectively.⁹ Finally, claims coded with body parts affected of lung(s), pleura, or body systems (Occupational Injury and Illness Classification System body part codes 225 and 5, respectively) were selected for review.⁹ Claim identification numbers were used to remove duplicate claims identified across both the asthma surveillance system and workers' compensation data.

Case Ascertainment and Characteristics

Potential workers' compensation cases (n = 480) were reviewed independently by both authors to determine inclusion based on the following case definition: respiratory disease or any type of airway irritation triggered by exposure to hop plant, hop dust, or hop extract. Discrepancies between the authors concerning case inclusion were resolved through additional medical record review (n = 12). Cases that lacked information were deemed unclassifiable (n = 70) and could not be evaluated. Examples of cases that did not meet the case definition include hop workers with asthma exacerbation from an insect sting or attributed to exposure to grass pollen. Although the entire medical record was used to establish respiratory disease associated with hop dust exposure, the primary diagnosis assigned to a given case was the *International Classification of Diseases, Ninth Revision* (ICD-9) code assigned by the health care practitioner on the RIIOD form (Table 1).¹⁰

Case characteristics obtained from the RIIOD form included length of time employed at the establishment where the injury occurred, the initial site of medical care, and the year of injury. Job title is given on the RIIOD form, but additional details in the medical records were used to further clarify job title, tasks, and the work process.

Case Series

For claim adjudication purposes within the Washington State Fund, the injured or ill workers' medical records are obtained from the past and current health care practitioners. Claimant medical

Table 1

Diagnosis ^a	No. (%) of patients (N = 57)
Asthma and acute bronchospasm	35 (61)
Obstructive disease	4 (7)
Allergic or other respiratory disorders	10 (18)
Symptoms consistent with asthma or respiratory distress	8 (14)

^aRefers to the primary diagnosis given at claim initiation by the attending physician using the *International Classification of Diseases, Ninth Revision* (ICD-9) coding system.

evaluations are guided by the attending health care practitioner on the claim. In Washington, workers select their attending health care practitioners, and the opinions of these practitioners are given preferential legal standing in causality and disability determinations.

We selected 3 hop-induced respiratory disease cases where medical documentation included evaluations by the attending physician and a medical specialist, such as a pulmonologist, or allergist-immunologist. The available records were summarized.

Incidence Rate

The rate of hop-induced respiratory disease was calculated using the 2 risk classifications that defined the hop industry with the highest specificity: hop farms (43 cases) and hop pellet manufacturing (1 case, Table 2). The rate of disease was calculated by dividing the total number of cases in these 2 risk classifications ($n = 44$ cases) by the total number of full-time equivalent (FTE) workers reported by employers into those same classifications during the period 1995 to 2011 ($n = 29,372$ FTE workers). Of the 2 classifications, hop farms represented most workers (28,554 FTE workers) during the study period. A comparison group of respiratory disease cases was defined using workers in the industrial risk classification of field vegetable crop farms. This classification covers establishments engaged in raising field vegetable crops that are mechanically harvested, such as beans, carrots, corn, and potatoes. The methods for extracting and identifying comparison group cases from the workers' compensation system were the same as that described for the hop industry. The case definition used was (1) any type of respiratory disease or airway irritation and (2) exposure to any dust, smoke, or chemical during the work.

Results

Primary Diagnosis and Case Series

A total of 57 cases of respiratory disease from exposure to hop dust were reported into Washington's workers' industrial insurance system from 1995 to 2011. The cases were distributed equally among the 3 distinct hop-growing areas of Washington's Yakima Valley and occurred predominantly during the annual harvest that runs from late August through early October. Most affected workers were male (89%), and the median age of workers was 31 years. Although race data were not available in the medical records, 42% of injured workers used Spanish language services during the management of their workers' compensation claim. Most workers ($n = 35$ [61%]; Table 1) were diagnosed as having asthma or acute bronchospasm, and 4 (7%) were diagnosed as having obstructive lung disease. The remaining workers were diagnosed as having allergic or other respiratory disorders (eg, allergic rhinitis) and symptoms associated with asthma or respiratory distress (eg, dyspnea). The mean (SD) number of cases filed per year was 3.4 (1.8), with a range of 0 to 7 cases reported per year. Most hop-exposed workers ($n = 40$ [70%]) received medical treatment at the emergency department, although some received care from a health clinic ($n = 17$ [30%]). Respiratory disease affected not only new workers employed for less than 1 year ($n = 13$ [23%]; Table 3) but also employees with more than 20 years of experience working for their employer ($n = 5$ [9%]). Employment length refers to the months worked for the employer at the time the workers' compensation claim was filed. It does not reflect potential hop dust exposure from previous jobs within the hop industry. For 3 patients, the medical records document with sufficient detail the association of work-related hop dust exposure and respiratory symptoms.

Patient 1 was a 27-year-old, previously healthy, nonsmoking man who presented to an emergency department with a 2- to 3-month history of cough and difficulty breathing associated with exposure to hop dust at work. He reported nocturnal wheezing in the

Table 2

Incidence rate of hop-induced respiratory disease in hop farming compared with respiratory disease in field vegetable crop farming

Risk classifications ^a	Total No. of FTE workers	No. of cases	Case rate per 10,000 FTE workers
Hop industry ^b	29,372	44	15.0
Field vegetable crop farms ^c	41,927	2	0.5

Abbreviation: FTE, full-time equivalent.

^aClassification for Washington workers' compensation insurance.

^bRate calculation defines hop industry as cases occurring within the risk classifications of hop and mint farms ($n = 43$ and 28,554 FTE workers) and hop pellet manufacturing.

^cField vegetable crop farms include establishments engaged in raising field vegetable crops that are mechanically harvested. Examples of field vegetables include beans, carrots, corn, potatoes, and tomatoes.

preceding month. He was afebrile and had occasional wheezes on physical examination, with a clear chest radiograph. His physician diagnosed an irritative bronchitis with bronchospasm. He responded to treatment with inhaled β -agonists and inhaled corticosteroids (beclomethasone, 168 μ g 4 times daily of unknown duration). He was asymptomatic until he had a recurrence of his symptoms on reexposure to hop dust during the following year's annual harvest. He was again treated with inhaled β -agonists, cromolyn sodium, and inhaled corticosteroids (beclomethasone, 84–168 μ g every 6 hours of unknown duration), and his symptoms improved after a 2-week placement in a work area with the lowest hop dust exposure. Subsequent allergy and immunology evaluation revealed pale nasal mucosa with swollen turbinates and a nasal smear with eosinophils present. Prebronchodilator spirometry revealed the following: forced vital capacity (FVC), 3.93 L (63%); forced expiratory volume in 1 second (FEV₁), 3.20 L (62%); and FEV₁/FVC ratio, 81%. Postbronchodilator spirometry revealed the following: FVC, 5.07 L (81%); FEV₁, 4.59 L (89%); and FEV₁/FVC ratio, 90%. Skin test results for inhalants were positive to hop, grass, 8 of 8 types of tree pollen, 10 of 10 types of weed pollen, dust mites, and cat. The allergy and immunology referral rendered diagnoses of allergic rhinitis and asthma.

Patient 2 was a 58-year-old, healthy, nonsmoking man with no known history of asthma who presented to an emergency department with the onset of chest tightness, shortness of breath, cough, and wheezing associated with the field harvest activity of stacking cut hop vines onto a truck trailer. The work task was noted to be excessively dusty, and he did not wear respiratory protection. He had been employed as a laborer for 3 years on a diversified hop and tree fruit farm. Initial medical evaluation documented a family history of asthma and no known preceding history of drug or environmental allergies. He was afebrile and was found to have bilateral inspiratory and expiratory wheezes on physical examination. Pulse oximetry on room air was 89% to 91%. The worker was hospitalized, and his respiratory status improved after administration of methylprednisolone, 125 mg intramuscularly, oral prednisone (20 mg twice daily), theophylline (300 mg twice daily), and inhaled β -agonists. With a 10-day oral steroid taper, initiation of inhaled corticosteroids (flunisolide, 0.5 mg twice daily), inhaled β -agonists, theophylline (300 mg twice daily), and work restriction

Table 3

Years working for employer before filing a workers' compensation claim for hop-induced respiratory disease

Employment length, y	No. (%) of workers (N = 57)
<1	13 (23)
1–2	8 (14)
3–5	20 (35)
6–10	6 (11)
11–19	5 (9)
>20	5 (9)

from potential hop dust exposure, his symptoms continued to improve during the next 2 months. He continued agricultural work as a laborer in a fruit orchard. During the next 3 years, he reported exacerbations of his chest symptoms with exposure to nonhop agricultural dusts and common environmental irritants. He received a disability award for permanent respiratory impairment 3 years after his initial presentation. At the rating examination for disability, prebronchodilator spirometry revealed the following: FVC, 3.62 L (104%); FEV₁, 2.21 L (88%); and FEV₁/FVC, 61%. Postbronchodilator spirometry revealed the following: FVC, 3.58 L (103%); FEV₁, 2.47 L (98%); and FEV₁/FVC, 69%. The pulmonologist noted that test reproducibility was compromised by poor test performance secondary to poor comprehension of test instructions.

Patient 3 was a previously healthy, 26-year-old male hop processing worker with 4 years of work experience who noted the onset of recurrent wheezes, chest tightness, and cough after the installation and his use of new, larger machinery to produce hop pellets for export. He described an increase in his symptoms during certain work tasks that generate a high volume of dust, specifically, clearing the clogged filters of the pelletizing machine. He noted improvement in symptoms during weekends with no work exposure. He had no reported history of childhood asthma, no family history of atopy, and no personal smoking history. He was afebrile, and his physical examination findings were unremarkable except for mild expiratory wheeze. He was diagnosed by his primary care physician as having work-related reactive airways disease and was treated with β -agonists and oral corticosteroids (20 mg twice daily for 4 days) and was told to wear a mask at all times. Subsequent evaluation by a pulmonologist led to the identification of nasal polyposis and a methacholine challenge test result "demonstrating a decline in flow rates, suggesting a positive diagnosis of airway hypersensitivity."

Incidence Rate and Work Activities Associated with Disease

The incidence rate of hop-induced respiratory disease for workers classified as working on hop and mint farms was 15 cases per 10,000 FTE workers, and this was 30 times greater than the rate of respiratory disease occurring in workers classified as working in field vegetable crop farms (Table 2). A wide variety of job titles were associated with hop-induced respiratory disease. Most cases (n = 31 [54%]; Table 4) occurred at the farm's harvest facility during the harvest. Cases of respiratory disease were observed in postharvest activities, such as extract and pellet processing, as well as in a laboratory technician (Table 4). Of interest, 2 administrative workers from different farms had indirect exposure to hop dust that migrated from the harvest process area into their office (Table 4).

Discussion

We identified 57 workers' compensation cases for respiratory disease associated with exposure to hop dust. The incidence rate of hop-induced respiratory disease was 30 times greater in hop farmers than the incidence rate of respiratory disease for field vegetable crop farmers, a comparable working population.

Góra et al¹¹ found more than 50% of Polish hop growers had work-related symptoms, with most symptoms (39%) respiratory in nature, followed by mucous and skin irritation (33%). Góra et al¹¹ also found that the prevalence of work-related respiratory symptoms in hop growers was similar to pig farmers and grain handling farmers but lower than in herb processing farmers. Although instances of dermatitis occurred among the respiratory cases presented here, the characterization of hop-related dermatitis was beyond the scope of this study. Hop-related dermatitis has presented as airborne dermatitis, hand dermatitis, and pruritis,¹² facial dermatitis and conjunctivitis,^{13,14} and contact urticaria.¹⁴

There is recognition within the hop-growing region in Washington State that hop dust is an allergen. Acknowledging that cases

Table 4

Job title and work process associated with hop-induced respiratory disease

Location (job title or process)	Total No. of cases	No. of asthma and acute bronchospasm cases
Harvest facility		
Hop sweeper	6	4
Hop hanger	5	3
Hop baling	3	0
Clean up dust	2	2
Hop packaging/sacks	2	1
Hop picking machine	2	1
Kiln operator	2	2
Maintenance of processing equipment	2	1
Machine operator	2	2
Cold room storage blow down	1	1
Conveyor operator	1	1
Truck driver	1	1
Unknown	2	1
Total	31	20
Hop field		
Field harvest	5	4
Hop plant tying	1	0
Truck driver	1	1
Unknown	3	2
Total	10	7
Extract facility		
Carbon dioxide extract processing	4	2
Maintenance of processing equipment	1	1
Total	5	3
Pellet plant production	2	2
Office worker on hop farm	2	2
Laboratory technician	1	1
Unknown location		
Machine maintenance	1	0
Unknown	5	0
Total	6	0
Total	57	35

occurred throughout nearly all phases of hop harvest, including indirect exposure, underscores either the combined or independent effect of dust pervasiveness and/or dust potency. Although the ubiquitous nature of hop dust surely poses a challenge to disease prevention, the systematic review of tasks associated with symptoms suggest some activities could be targeted for reducing the risk of disease. Several cases were associated with concentrated high dust exposures, such as dry broom sweeping; compressed-air dust blow downs; maintenance on processing equipment, including filter changing; and hop bale making (concentrated final product). Prevention measures that could be implemented include local exhaust ventilation, procedure changes, restricted access, and respiratory protection. Cases were observed for both newly employed workers and tenured workers. Workers with different levels of experience would benefit from targeted disease prevention activities. The wide range of job titles and work locations associated with respiratory disease suggests that returning a sensitized or symptomatic worker to the environment will be difficult. Few, if any, jobs within the harvest process are likely to be hop dust free.

Our observations from these 57 cases support an argument that hop dust causes or aggravates preexisting respiratory disease.¹⁵ The 3 medical cases described in detail provide strong evidence of a temporal association between hop dust exposure and the subsequent development of respiratory symptoms. All 3 patients reported no respiratory disease before exposure to hop dust. Symptoms were specific to the annual hop harvest or hop processing tasks. The respiratory symptoms dissipated during the periods after the harvest or with lessened exposure to hop dust. The medical history supports symptom onset with increased, short-term exposure to hop dust either in the stacking of hop vines in a truck trailer (case 2) or in the transition from a smaller to a larger hop pelletizer (case 3).

The significantly elevated respiratory disease incidence rate in hop workers relative to the comparison group suggests an association between hop dust exposure and respiratory disease and is consistent with the results of other researchers to support a causative association between hop dust exposure and respiratory disease.^{1,11}

One limitation of this work concerns case underreporting. Work-related asthma is generally thought to be underrecognized and poorly evaluated.¹⁶ Barriers to accessing the workers' compensation system include a lack of knowledge of the system, language other than English, beliefs about eligibility, and fear of job loss or retribution.¹⁷ Finally, symptomatic hop workers may transfer to harvesting a different crop, such as apples, and are unlikely to visit a health care practitioner if their symptoms resolve.

A second limitation is that the dust exposures associated with the cases were not characterized. The contribution of bioaerosols and crop pests as causative agents could not be evaluated in this retrospective review. Bioaerosols are expected to be present in agricultural hop dust and are generally accepted as asthmagens and respiratory irritants. Hop, however, has been found to have antimicrobial properties, and it has been hypothesized that these antimicrobial properties may be associated with reduced bioaerosol concentrations.^{11,18} Indeed, Góra et al¹¹ concluded that the bioaerosol exposure in hop farms was lower than bioaerosol exposure in many other agricultural settings, such as herb and flax processing, grain handling, poultry farming, cattle breeding, and pig raising. Although the overall bioaerosol concentrations may be lower than other farm settings, Góra et al concluded that for the microbial factors that were present, bacterial endotoxin and allergenic fungi pose the greatest potential hazard for exposed hop farmers. In addition, arthropod pests, such as the 2-spotted spider mite (*Tetranychus urticae*), are damaging pests in Washington hop yards. Skin prick testing in a cross-sectional survey of 119 symptomatic apple farmers revealed the two-spotted spider mite to be a sensitizing allergen.¹⁹

Finally, the medical data submitted to Washington L&I represents the standard of care provided to workers in the community. These medical evaluations are often deficient in (1) assessing the work environment and its hazardous exposures, (2) documenting the worker's symptom history, and (3) using objective testing of respiratory disease and its association with work (ie, tests of bronchial hyperresponsiveness and workplace challenge testing).¹⁶ The diagnosis of asthma was provided by the health care practitioner. Among the 57 cases, there was often insufficient information to classify the cases as work aggravated, occupational asthma with latency, or occupational asthma without latency, all of which may be feasible diagnoses in this population of workers. Nevertheless, there is a consistent association of hop dust exposure to respiratory disease onset during the 15-year observation period of our study with little alternative explanation as to the why there is elevated risk of respiratory disease in these workers.

This cluster of cases was identified within a social insurance system designed to provide workers' benefits for injuries and illnesses from the workplace. Efforts to systematically identify cases of work-related asthma from hop dust exposure and early referral to medical specialists able to evaluate the medical and immunologic aspects of the disease will improve our understanding of the association between hop dust and respiratory disease. Such referrals likely will improve the diagnostic and clinical care of workers with suspected occupational asthma. Asthma caused by allergic sensitization to occupational exposures often requires complete cessation of exposure and counseling regarding leaving the work environment. When an appropriate diagnostic evaluation is performed, one can have reasonable confidence in recommending removal from ongoing

exposure. A worker's prognosis improves with early recognition of the disease and cessation of the offending exposure.

Identification of the allergenic constituent(s) of the hop plant *Humulus lupulus* would help medical diagnosis; currently, the causative agent is unclear. Positive skin reactions have been documented for exposure to the collective chemical constituents present in hop cone extract, hop leaf extract, and simply hop extract.^{1,3,11,12,20} One specific constituent, the terpene B-myrcene present in hop oil, elicited a positive patch test result at 4 and 48 hours after administration to a brewery worker.¹

Overall, this cluster of cases demonstrates the value of nationally supported regional occupational disease surveillance because the state's occupational asthma surveillance system was critical in identifying the cases. The surveillance system allows for the identification of asthma-causing agents most relevant to the regional workforce.

Occupational exposure to hop dust likely causes respiratory disease. Disease occurred in workers involved in all phases of the hop harvest and processing. Further characterization of hop dust allergen(s), dust exposure in hop harvest and processing, and the prevalence of respiratory symptoms in workers is needed to develop effective disease prevention strategies.

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