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WORK RELATED RESPIRATORY DISEASE

Work-Related Asthma in Washington State

NAOMI J. ANDERSON, M.P.H.,* CAROLYN K. REEB-WHITAKER, M.S., C.I.H., DAVID K. BONAUTO, M.D., M.P.H., AND EDMUND RAUSER, B.S., P.E.

Washington State Department of Labor and Industries, SHARP Program, Olympia, WA, USA.

Objective. Asthma is a common and costly public health problem. Occupational exposures contribute to the burden of asthma. Identifying workplace exposures and industries and occupations at risk can lead to more effective prevention measures. *Methods*. Data from Washington State's work-related asthma (WRA) surveillance program from October 2001 to December 2008 were analyzed. Workers' compensation records, physician reports, and telephone interviews were used to describe the occurrence of WRA during this time, in order to identify contributing exposure sources and industries and occupations that are associated with WRA in Washington. *Results*. There were 1343 identified WRA cases in Washington State during this time. Of these, 1285 were workers' compensation claims, with a total medical cost for State Fund claims of approximately $3 million dollars. The top three sources identified were miscellaneous chemicals and materials, mineral and inorganic dusts, and plant material. Plant material claims proved to be widespread throughout various industries, were largely classified as new-onset asthma cases, and had higher median medical cost and higher median time loss days than cases associated with other exposure sources. *Conclusions*. Washington State has an abundance of plant-material-related WRA cases among US states conducting WRA surveillance. Washington State's industry mix might explain the higher prevalence of cases, particularly its logging and wood processing industries and as a world leader in hops production. In Washington, further WRA prevention efforts should emphasize workplaces working with plant materials.

Keywords asthma, new-onset asthma, occupational asthma, plant material, surveillance, work-aggravated asthma, work-related asthma

INTRODUCTION

Asthma is a serious, common, and costly lung disease. In the United States in 2004, an estimated 14.4 million people had current asthma (1). Occupational exposures likely contribute to a large proportion of adult asthma, with estimates ranging from 5% to 44% (2–4). Additionally, adult-onset occupational asthma may be more severe than non-occupational asthma (5) and lead to higher healthcare utilization and poorer asthma control (6). A 1999 estimate of the direct and indirect costs of occupational asthma was $1.5 billion dollars (7).

There are over 350 substances that have been identified as being possible work-related asthma (WRA) sensitizers or known to cause WRA (8), and the list grows regularly.

Washington State is an agricultural state, producing apples, cherries, grapes, potatoes, hops, wheat, hay, raspberries, and many other products. Washington is also known for its forestry and logging as well as secondary wood processing manufacturing. Types of wood include a variety of hardwoods as well as softwood species including Western Red Cedar. There is limited discussion in the occupational asthma literature about plant material exposures and their public health impact. Results from the four US states (CA, MA, MI, NJ) that conduct WRA surveillance as part of the Sentinel Event Notification Systems for Occupational Risks (SENSOR) Program do not include plant material in their top 10 reported sources (9), and wood dusts are ranked 27th. An earlier study of WRA in California reported plant material (not including wood dusts) as tied for the fifth highest number of cases (10). Reviews of respiratory diseases and exposure to wood dusts (11, 12) found a consistent pattern of elevated prevalence and odds ratios of asthma and asthmatic symptoms for both fresh (11) and dry (12) wood dust industries. Besides wood dusts, other generic organic dusts have been found to be associated with respiratory symptoms (13, 14). While a number of specific plants and plant materials have been associated with respiratory symptoms such as hops in farm or brewery workers (15, 16) and cannabis in hemp workers (17), these tend to be sporadic and narrowly focused on one plant or industry.

We analyzed data from the Washington State WRA surveillance program from October 2001 to December 2008. We describe the burden of asthma using workers' compensation records and telephone interviews; and identify the exposure sources that contribute and the industries and occupations that are associated with WRA in Washington. This study describes the overall results of a WRA surveillance program, and focuses on more thoroughly describing the plant material asthmagens found therein.

Characterizing the nature and experience of occupational asthma, especially the role of plant material, can be used to prioritize prevention resources.

METHODS

Washington's Workers' Compensation System

In Washington State, nonfederal employers are required to obtain workers' compensation insurance through the

*Corresponding author: Naomi J. Anderson, M.P.H., Washington State Department of Labor and Industries, SHARP Program, PO Box 44330, Olympia, WA 98504-4330, USA; Tel: +360 902-4957; Fax: +360 902 -5672; E-mail: anna235@lni.wa.gov

Department of Labor and Industries (L&I), unless they meet specific requirements to self-insure or are covered under an alternative workers' compensation program (e.g., Longshore and Harbor Workers' Compensation Act). The department administers the State Fund (SF), an industrial insurance program that provides coverage for approximately 1.9 million (about two-thirds) of the workers in the state and 99.7% of all employers. Accepted claims can be categorized into compensable and noncompensable claims. Compensable claims are those with the claim status codes "compensable," "kept on salary," "total permanent disability," "fatal," or "loss of earning power." Accepted claims that are noncompensable are medical-only claims.

Workers' compensation claim costs represent costs paid to date for closed claims, and for those claims that remained open on the date of extraction, the claim costs represent those paid to date and an estimate by the workers' compensation case reserve unit of future expected claim costs. Costs are not adjusted for inflation. Indirect costs to employers and workers and the administrative costs of managing the claim are not included in the claim costs.

Data from both SF and self-insurance programs are collected and entered in a centralized database at L&I. However, medical records, cost and disability information about self-insured claims are typically incomplete. Because of this, the surveillance system and medical record review described here reflects primarily SF insured workers. Physicians may also report cases directly to the Safety and Health Assessment and Research for Prevention Program, regardless of source of insurance, through confidential case reporting. Occupational asthma is a reportable condition in Washington State (WAC 246-10-101, WAC 246-10-301) for healthcare providers and healthcare facilities.

Employer accounts are assigned a North American Industry Classification System (NAICS) code and a Standard Occupational Classification (2000) code (18) is assigned to the injured worker from the claim information.

Asthma Surveillance Database

In Washington State, the worker and physician initiate a workers' compensation claim by completing a Report of Industrial Injury or Occupational Disease (RIIOD) form. The worker and healthcare provider provide a narrative description of the injury event and diagnoses, respectively, on the RIIOD. Information from the RIIOD form is entered into L&I's workers' compensation claims database for all SF claims.

All claims received with the word "asthma" on the RIIOD and certain claim information including employer, industry and occupation codes, and claim cost data are extracted monthly from the Workers' Compensation database and imported into a Washington's Asthma Surveillance Database. An analyst views the RIIOD form and other available medical and administrative records associated to verify that the claim was filed for work-related asthma.

Case Ascertainment

All claims received in the Asthma Surveillance Database from October 2001 to December 2008 were identified for inclusion in this report. The time period chosen includes all cases collected from the time follow-up interviews began in October 2001.

Asthma Follow-Up Interviews

Claims received in the asthma surveillance database are reviewed and follow-up materials are mailed to each claimant. The follow-up materials introduce our surveillance program to the injured worker and briefly explain why they were contacted; the materials also provide educational information about WRA and inform them that they may be selected for a follow-up telephone interview. Cases (regardless of claim status) are interviewed by phone to gather additional data, including information on workplace exposures and medical history. The surveillance protocols, telephone follow-up interview, as well as all follow-up materials were approved by the Washington State Institutional Review Board.

Asthma Classifications

WRA consists of two groups: occupational asthma and work-aggravated asthma (WAA). Occupational asthma is generally considered new onset and is broken down into occupational asthma with latency (new-onset asthma, NOA) and occupational asthma without latency. Latency describes the period between the beginning of exposure and the development of symptoms. Occupational asthma without latency is also called Reactive Airways Dysfunction Syndrome (RADS) (19). WAA refers to pre-existing asthma which is made worse by workplace exposures.

Following a completed interview, the claim information and questionnaire responses are reviewed (by an epidemiologist, an industrial hygienist, and an occupational medicine physician) and classified according to the SENSOR asthma case classification scheme for occupational asthma (20).

Asthma source agents are coded using the Association of Occupational and Environmental Clinics (AOEC) exposure code list (8). Determination of the primary asthma source, as well as up to four additional sources, is made based on open-ended interview questions regarding job tasks and an explanation of the situation the worker believes caused their asthma.

AOEC Coding

The AOEC exposure code system lists exposures which may cause asthma and gives them a hierarchical numerical (code) designation (8). The system includes the name of the substance, synonyms, and further designations for substances that may be reported as asthmagens, solvents, pesticides, sensitizers, agents involved in RADS, and the like; as well as Registry of Toxic Effects of Chemical Substances numbers and Chemical Abstracts Service numbers, where available. The list (and further

information) can be found on the AOEC website, and is updated periodically (8).

Typically, the AOEC source code is assigned using information obtained during the follow-up interview. Where claims had incomplete or no interview, an AOEC code was assigned by medical record review when possible (21).

Statistical Analysis

Descriptive statistics such as frequencies and percents as well as tests of statistical significance (Wilcoxon rank sum) were calculated using SAS 9.1 (SAS Institute, Inc., Cary, NC, USA).

RESULTS

Overview of All Asthma Claims in Washington State

From October 2001 to 31 December 2008, L&I received 1343 claims for WRA (1285 from SF and self-insurance workers' compensation, 58 from physician reported). Most claimants were in the age range of 25–64 years (89%) and more than half the claimants were female (57%, see Table 1). Among these asthma claims, 37% were rejected by L&I, 40.1% were noncompensable, and 17.8% were compensable (Table 1). Claims were rejected for a variety of reasons—primarily as "not the result of the injury/exposure alleged" (33%) or due to "no proof of specific injury at a definite time and place in the course of employment" (32%) or "not a result of the industrial injury as defined" or "not an occupational disease" or "pre-existing" (11%). Additional reasons for rejection included administrative issues (claim should have been sent to self-insured, duplicates, no physician report attached, or falling into another state or federal jurisdiction; 20%); not considered (or able to be verified as) a worker (2%); or no personal injury sustained (reactions to inoculation, stress; 2%). The SF claims had a total claim cost of more than $11 million dollars (Table 1).

Of the 605 workers who subsequently completed a follow-up interview, 531 (88%) had reported undergoing breathing tests to diagnose their asthma, and 440 (73%) had been diagnosed with asthma by a physician.

Occupation

The majority of asthma claimants were production workers (14%) and office and administrative support (13%) (Table 2). Healthcare and healthcare support occupations totaled 11% collectively, followed by occupations related to transportation (8%) and construction (7%).

NAICS Industry Sector

By NAICS industry sector (two-digit level) codes, most claims filed were from the manufacturing sector (16%) followed by healthcare and social assistance (15%) (Table 3). Educational services and public administration each represent 10% of the claims while all other two-digit sectors make up 8% or less of the remaining claims.

TABLE 1.—Demographic, claim, and asthma characteristics of 1343 cases of work-related asthma in Washington State, 2001–2008.

	Frequency	Percent
Total	$n = 1343$	
Female	767	57.1
Age group		
15–24	134	10.0
25–34	270	20.1
35–44	328	24.4
45–54	402	29.9
55–64	190	14.1
65+	11	0.8
Missing	8	0.6
Claim status		
Total compensable	249	17.8
Compensable	225	16.8
Fatal	3	0.2
Total permanent disability	15	1.1
Kept on salary	6	0.4
Noncompensable	538	40.1
Rejected	497	37.0
Not yet allowed	1	0.1
Physician-reported cases	58	4.3
Costs (workers' compensation claims only)	$n = 1285$	
Total claim cost ($)	11,730,227	
Plant material as exposure agent ($n = 142$)	1,458,135	
Median claim costs ($)		
Compensable claims	$n = 249$	
Plant material ($n = 34$)	12,556 (Q1–Q3[a]: 2605–38,245)	$p < .01$[b]
All other exposure agents ($n = 215$)	3223 (Q1–Q3: 598–23,653)	–
Medical-only claims (noncompensable)	$n = 538$	
Plant material ($n = 66$)	505 (Q1–Q3: 197–1253)	$p < .08$
All other exposure agents ($n = 472$)	388 (Q1–Q3: 155–835)	–
Compensable claims only	$n = 249$	
Median time loss days (number of days)	6	
Plant material	26 (Q1,Q3: 4, 286)	$p < .01$
All other exposures	4 (Q1,Q3: 0, 54)	–
For those with completed follow-up questionnaires:	$n = 605$	
Asthma classification		
New-onset asthma	335	55.4
RADS	65	10.7
Work-aggravated asthma	268	44.3
Other	2	0.3

Note: [a]Q1–Q3 are the first and third quartiles, for interquartile range.
[b]All reported *p*-values are Wilcoxon rank sum test.

Asthma Classification—Occupational Asthma and Work-Aggravated Asthma

Asthma classification was determined for cases with a follow-up interview ($n = 605$) (21). Approximately 55% of interviewed workers had occupational asthma (including 11% RADS) and another 44% suffered from WAA (Table 1).

TABLE 2.—Number of claims by Standard Occupational Classification (SOC) code.

All cases[a]			Interviewed ($n = 605$)[b]						
Occupation (major groups)	Frequency	Percent	OA non-RADS	%	RADS	%	WAA	%	Total (OA, RADS, WAA)
Production	156	13.7	40	60.6	5	7.6	21	31.8	66
Office and administrative support	145	12.8	16	26.7	10	16.7	34	56.7	60
Transportation and material moving	95	8.4	22	57.9	4	10.5	12	31.6	38
Healthcare practitioners and technical	82	7.2	7	18.4	3	7.9	28	73.7	38
Construction and extraction	80	7.0	15	51.7	4	13.8	10	34.5	29
Sales and related	59	5.2	8	32.0	4	16.0	13	52.0	25
Building and grounds cleaning and maintenance	54	4.8	7	31.8	4	18.2	11	50.0	22
Installation, maintenance, and repair	50	4.4	13	59.1	2	9.1	7	31.8	22
Healthcare support	45	4.0	2	11.8	1	5.8	14	82.4	17
Farming, fishing, and forestry	44	3.9	11	68.8	3	18.7	2	12.5	16
Protective service	34	3.0	6	31.6	6	31.6	7	36.8	19
Food preparation and serving related	33	2.9	4	26.7	1	6.6	10	66.7	15
Management	31	2.7	8	50.0	2	12.5	6	37.5	16
Education, training, and library	27	2.4	6	54.5	–	–	5	45.5	11
Personal care and service	25	2.2	5	35.7	1	7.1	8	57.1	14
Business and financial operations	18	1.6	2	33.3	–	–	4	66.7	6
Community and social services	15	1.3	2	22.2	1	11.1	6	66.7	9
Life, physical, and social sciences	9	0.8	2	33.3	–	–	4	66.7	6
Architecture and engineering	8	0.7	3	42.8	2	28.6	2	28.6	7
Arts, design, entertainment, sports, and media	6	0.5	–	–	–	–	–	–	–
Computer and mathematical	4	0.4	–	–	–	–	3	100	3
Legal	3	0.3	–	–	–	–	2	100	2
Unknown	112	9.9	30	49.2	2	3.3	29	47.5	61
Total	1135	–	209	41.6	55	11	238	47.4	502

Note: [a] Washington State Fund only, excludes self-insured and physician-reported cases.
[b] Two other cases were classified as "other" and are not shown; an additional 100 lacked an occupation code (self-insured or physician reported).

NOA (including RADS) cases were found predominantly in the following industry sectors (Table 3): manufacturing (82%); agriculture, forestry, fishing, and hunting (76%); wholesale trade (67%); other services, except public administration (67%); construction (63%); educational services (56%); and professional, scientific, and technical services (54%). Cases were fairly evenly distributed between NOA and WAA in retail trade (46% NOA) and public administration (51% NOA). On the other hand, WAA was the most common class of asthma found in all other sectors (Table 3): arts, entertainment, and recreation (100%); utilities (100%); finance and insurance (80%); information (67%); accommodation and food services (60%); healthcare and social support (59%); administrative and support and waste management and remediation services (59%); and transportation and warehousing (57%).

Occupational Exposure Sources

The source agent(s) causing asthma differs between industries. It is important to note that claimants may report being exposed to more than one agent. The manufacturing sector had the most diverse list of asthma sources (21), and asthma in manufacturing predominantly resulted from exposure to plant material such as Western Red Cedar and not otherwise specified (NOS) wood dust (Table 5). Plant material (Table 5) was one of the predominant asthma sources in agriculture, along with miscellaneous chemicals (data not shown). In

TABLE 3.—Number of claims by two-digit NAICS industry sector[a].

All claims			Interviewed ($n = 605$)						
Industry sector	Frequency	Percent	OA non-RADS	%	RADS	%	WAA	%	Total
11—Agriculture, forestry, fishing, and hunting	61	4.7	19	65.5	3	10.4	7	24.1	29
21—Mining, quarrying, and oil and gas extraction	1	< 1	–	–	–	–	–	–	–
22—Utilities	4	< 1	–	–	–	–	2	100	2
23—Construction	86	6.6	20	52.6	4	10.5	14	36.8	38
31–33—Manufacturing	210	16.1	59	67.0	13	14.7	16	18.2	88
42—Wholesale trade	47	3.6	13	54.2	3	12.5	8	33.3	24
44–45—Retail trade	110	8.5	15	32.6	6	13.1	25	54.3	46
48–49—Transportation and warehousing	36	2.8	6	42.9	–	–	8	57.1	14
51—Information	16	1.2	–	–	1	33.3	2	66.7	3
52—Finance and insurance	31	2.4	2	20.0	–	–	8	80.0	10
53—Real estate and rental and leasing	24	1.8	4	33.3	1	8.3	7	58.3	12
54—Professional, scientific, and technical services	29	2.2	4	30.8	3	23.1	6	46.2	13
56—Administrative and support, and waste management and remediation services	96	7.4	11	32.4	3	8.8	20	58.8	34
61—Educational services	131	10.1	31	50.8	3	4.9	27	44.3	61
62—Healthcare and social assistance	189	14.5	28	30.8	9	9.9	54	59.3	91
71—Arts, entertainment, and recreation	9	< 1	–	–	–	–	2	100	2
72—Accommodation and food services	53	4.1	8	32.0	2	8.0	15	60.0	25
81—Other services (except public administration)	38	2.9	10	55.6	2	11.1	6	33.3	18
92—Public administration	131	10.1	26	35.1	12	16.2	36	48.7	74
Total	1302	100	256	43.8	65	11.1	263	45.0	584

Note: [a]An additional 41 claims had no industry information reported (13 physician-reported cases, 1 self-insured without claim information, and 27 workers' compensation claims that lacked any NAICS information). One industry sector, NAICS 55—management of companies and enterprises, did not appear in our data. Not all claims with a reported industry sector had agent/source information, and claims may report multiple sources.

construction, plant material (wood dust), and mineral and inorganic dusts (data not shown) were the predominate sources, followed by miscellaneous chemicals (data not shown). It is beyond the scope of this article to display the details on other sources (21). In summary, however, nonplant sources were distributed as follows: in healthcare, asthma claims were dominated by miscellaneous chemicals more than in other industries. Examples of miscellaneous chemicals in healthcare included NOS perfume, indoor air quality (IAQ), and indoor air pollutants from building renovation. Additionally, NOS dust and NOS mold were also common in healthcare. The predominant asthma sources in educational services and public administration were very similar and driven by exposure to NOS mold, NOS dust, IAQ, and IAQ from building renovation. Educational services also included several claims from NOS perfume, while public administration included claims from smoke/NOS fumes.

All asthma sources grouped at the three-digit AOEC code (Table 4) hierarchy show the dominant exposure source in Washington State is "miscellaneous chemicals and materials, referenced by use." This makes sense as the category includes a large number of generic exposure categories such as: IAQ; IAQ from building renovation; NOS chemicals; NOS paints; NOS perfume; and NOS cleaning materials. This was followed by "mineral and inorganic dusts" and "plant materials."

Exposure Source and Asthma Classification. Asthma exposure source is summarized here by the primary source agent (claims had from one to three primary sources). There were differences in the distribution of exposure sources between classes of asthma (Table 4).

The following sources resulted predominantly in occupational asthma claims: metals and metalloids (86%); acids, bases, and oxidizing agents (80%); halogens, inorganic (78%); isocyanates (80%); ketones (79%); animal material (68%); plant material (64%); mineral

TABLE 4.—Frequency of major groups of exposure agents.

Rank	AOEC code[a] —description	All primary sources	Interviewed ($n = 605$) OA non-RADS	%	RADS	%	WAA	%	Total
1	320—Miscellaneous chemicals and materials, referenced by use	494	104	37.5	28	10.1	145	52.4	277
2	010—Mineral and inorganic dusts	182	38	51.3	9	12.2	27	36.5	74
3	370—Plant material	164	48	56.4	6	7.1	31	36.5	85
4	390—Microorganisms	142	41	51.9	5	6.3	33	41.8	79
5	330—Pyrolysis products	111	20	37.0	7	13.0	27	50.0	54
6	170—Hydrocarbons, not otherwise specified	85	19	40.4	11	23.4	17	36.2	47
7	020—Metals and metalloids	50	17	81.0	1	4.7	3	14.3	21
8	380—Animal material	48	15	68.2	–	–	7	31.8	22
9	060—Aliphatic and alicyclic hydrocarbons	44	6	21.4	1	3.6	21	75.0	28
10	360—Ergonomic factors (exercise)	36	4	23.5	–	–	13	76.5	17
11	050—Acids, bases, and oxidizing agents	27	5	50.0	3	30.0	2	20.0	10
12	220—Isocyanates	27	12	80.0	–	–	3	20.0	15
13	040—Miscellaneous inorganic compounds	24	4	26.7	1	6.7	10	66.7	15
14	270—Polymers	23	4	44.4	1	11.1	4	44.4	9
15	130—Ketones	18	6	42.9	5	35.7	3	21.4	14
16	030—Halogens (inorganic)	16	6	66.7	1	11.1	2	22.2	9
17	350—Physical factors	14	1	16.7	–	–	5	83.3	6
18	160—Aromatic hydrocarbons	11	1	12.5	3	37.5	4	50.0	8
19	110—Epoxy compounds	9	1	25.0	–	–	3	75.0	4
20	120—Aldehydes and acetals	9	1	50.0	–	–	1	50.0	2
21	070—Alcohols	6	2	50.0	–	–	2	50.0	4
22	190—Halogenated aliphatic hydrocarbons (except organochlorine pesticides)	4	1	50.0	1	50.0	–	–	2
23	140—Esters	3	3	100	–	–	–	–	3
24	090—Glycol ethers	2	–	–	1	100	–	–	1
25	180—Phenols and phenolic compounds	2	–	–	–	–	1	100	1
26	080—Glycols	1	–	–	1	100	–	–	1
27	150—Carboxylic acids and anhydrides	1	1	100	–	–	–	–	1
28	250—Aromatic nitro and amino compounds (including heterocyclic)	1	–	–	–	–	1	100	1
29	310—Organic sulfur compounds	1	–	–	–	–	–	–	–
Total		1555	360	44.4	85	10.5	365	45.1	810[b]

Note: [a]Association of Occupational and Environmental Clinics (AOEC) exposure codes: http://www.aoec.org/tools.htm
[b]Claims can report more than one source.

and inorganic dusts (64%); hydrocarbons NOS (64%); microorganisms (58%); and polymers (56%). In categories with few claims, NOA was the only classification in esters (three claims); halogenated aliphatic hydrocarbons (two claims); carboxylic acids and anhydrides (one claim); glycols (one claim), and glycol ethers (one claim).

The following sources resulted predominantly in WAA claims: physical factors (83%); ergonomic factors (77%); aliphatic and alicyclic hydrocarbons (75%);

miscellaneous inorganic compounds (67%); and epoxy compounds (75%). In small categories, WAA was the only classification in phenols and phenolic compounds (one claim); and aromatic nitro and amino compounds (one claim).

Occupational asthma and WAA were evenly split in pyrolysis products (50% NOA); alcohols (50% NOA); aldehydes and acetals (50% NOA); aromatic hydrocarbons (50% NOA); and miscellaneous chemicals referenced by use (48% NOA).

Asthma Caused by Plant Materials

Asthma-causing agents, asthmagens, differ by industry and industries differ from state to state. Washington has several industries that involve the manufacturing, processing, and handling of plant asthmagens (e.g., agriculture and logging, wood products manufacturing, and agriculture-related warehouse and transportation), and this industry profile is reflected in the abundance of WRA cases associated with plant material.

There were a total of 142 claims filed for exposure to plant material; because injured workers can report exposure to more than 1 type of asthma source or to multiple plant materials, the total number of plant sources is 164. Asthma from plant materials occurs in 15 out of 20 NAICS sectors in Washington. Plant materials are the dominant asthma source for agriculture, forestry, fishing and hunting; construction; manufacturing; and transportation and warehousing. It is the second most common asthma agent in wholesale trade. See Table 5 for the complete breakdown of all plant material claims by six-digit NAICS industry. The total claim cost of these 142 plant-material-related WRA claims was approximately $1.4 million dollars; the median claim cost for compensable claims was $12,556, and the median time loss (compensable claims only) was 26 days.

Western Red Cedar and Wood Dusts NOC

Medical and claim records were further reviewed for a total of 63 unique cases for exposure to all types of wood dust. Seven cases listed more than one type of wood while five did not seem to be about wood; and four did not have medical records available for review. Overall, there were 36 cases with exposure to wood dusts NOS; 41 cases with exposure to Western Red Cedar; and 1 case each for exposure to Mahogany and tropical hardwoods NOS (see Table 5).

Wood dust exposure was concentrated in certain industries such as sawmills (eight cases, Table 5) and noticeably in the production of residential and garage doors (nine cases). Wood dusts were also found in production carpentry, residential construction, fencing, and other industries in manufacturing (Table 5) that used wood products (e.g., cedar chips) as well as transportation and warehousing industries that move or handle wood products.

Hops

There were a total of 13 cases reported for asthma due to hops (Table 5). Eight cases were reported from agriculture, and five additional cases were reported by the agriculture-related industries of wholesale trade and transportation and warehousing.

Other Plant Materials

Other specified plant materials causing asthma include paper dust (eight claims) in seven industries; hay (seven claims) in six industries (primarily in agriculture); and capsicum in five industries (six claims) (Table 5). Exposure to capsicum occurred from the use of mace or pepper spray, which includes capsicum as an ingredient. Injured workers exposed to capsicum were primarily related to security and public administration.

Plant material, NOS, was also a very common source, with 21 reported cases occurring in 11 sectors (20 industries). These cases included reports of various flowers, grasses and weeds, and other vegetation encountered across industries. There was one case of a law-enforcement officer chronically exposed to cannabis held and stored as evidence. Cannabis is in the same plant family as hops.

Costs

The total claim costs of the 142 plant-material-related WRA claims was over $1 million dollars; the median claim cost for compensable claims was $12,256 and the median time loss was 26 days (Table 1); the median claim cost for noncompensable was $505. The distribution was skewed with some very expensive claims, but in compensable claims the median claim cost and median time loss days were significantly higher for plant-material-related claims than for claims with other exposure sources (both $p < .01$, Table 1).

Discussion

WRA occurred across a variety of industries and occupations in Washington State, and the abundance of plant material cases found in this study reflects the nature of Washington's industries and climate. For example, WRA in the manufacturing sector resulted predominantly from exposure to plant materials, most notably Western Red Cedar and nonspecific wood dust, which highlights the role of the wood products industry in Washington. While certain industry sectors are associated with a wide variety of respiratory hazards (such as agriculture and manufacturing), the number, costs, and wide distribution of plant-material-related cases warranted a more in-depth look at the exposures in question.

There were also differences in the exposure sources found by our WRA surveillance program, as compared to the published reports by the four SENSOR states (CA, MA, MI, and NJ) (9). The top three exposure sources reported by the SENSOR states are "chemicals, NOS" (10%), followed by "dust" (9%), and "air pollutants, indoor" (9%) (9). In Washington, our top three main

TABLE 5.—Claims with plant material exposures by two-digit North American Industry Classification System (NAICS) sector and select four-digit NAICS industry group.

Industry sector and detail of industry groups with ≥3 claims[a]	Exposure source[b]										
	NOS[c]	370.01—Paper dust	370.03—Grain dust	370.08—Hay	370.16—Hops	370.35Capsicum	373.00—Wood dust NOS	Cedar	Other[d]	Plant material Total	All claims sector total
11—Agriculture, forestry, fishing, and hunting (sector total)	5		2	3	8		1	5	4	28	61
1113—Fruit and tree nut farming	2				3				1	6	
1119—Other crop farming					5				1	6	
1121—Cattle ranching and farming	1		2	2			1		2	8	
1133—Logging								3		3	
23—Construction (sector total)			1	1			10	11	3	26	86
2361—Residential building construction			1	1			3	3		8	
2381—Poured concrete foundation and structure contractors							5	5		10	
2389—Other specialty trade contractors							1	2	1	4	
31–33—Manufacturing (sector total)	1	2					19	21	5	48	210
3211—Sawmills and wood preservation								8		8	
3212—Veneer, plywood, and engineered wood product manufacturing							3	2		5	
3219—Other wood product manufacturing							8	8	1	17	
3371—Household and institutional furniture and kitchen cabinet manufacturing							3			3	
3399—Other miscellaneous manufacturing							2	1		3	
42—Wholesale trade (sector total)	1	1		2	3		1		2	10	47
4244—Grocery and related product merchant wholesalers					1				2	3	
4249—Miscellaneous nondurable goods merchant wholesalers	1	1		2						4	
44–55—Retail trade (sector total)	1			1				2	2	6	110
4452—Specialty food stores								1	2	3	
48–49—Transportation and warehousing (sector total)	3		2		2	1				8	36
4931—Warehousing and storage			1		2					3	
51—Information (sector total)	2									2	16
52—Finance and insurance (sector total)		1								1	31
53—Real estate and rental and leasing (sector total)									1	1	24
54—Professional, scientific, and technical services (sector total)	1			1		1				3	29
5416—Management, scientific, and technical consulting services	1			1		1				3	
56—Administrative and support and waste management and remediation services (sector total)	1	2		1		2	1		2	9	96
5613—Employment services		1					1		1	3	
5614—Business support services						2			1	3	
71—Arts, entertainment, and recreation (sector total)							1			1	9
72—Accommodation and food services (sector total)	1			1					1	3	53
5617—Services to building and dwellings	1	1		1						3	
61—Educational services (sector total)									1	1	131
62—Healthcare and social assistance (sector total)	2					1	2			5	189
81—Other services (except public administration) (sector total)							1			1	38
92—Public administration (sector total)	3	1		2		1			2	9	131
9211—Executive, legislative, and other general government support	2			1					1	4	
9221—Justice, public order, and safety activities	1			1		1			1	4	
Missing industry data								2		2	
Total	21	7	5	12	13	6	36	41	23	164	1302

Note: [a]The details of the complete distribution by NAICS six-digit industries are available from the author upon request; not all claims had industry/source information.
[b]Association of Occupational and Environmental Clinics (AOEC) exposure codes: http://www.aoec.org/tools.htm.
[c]Not otherwise specified.
[d]"Other" includes 370.001—herbal tea NOS (1); 370.003—organic dusts NOS (4); 370.04—vegetable dust (2); 370.07—grass cuttings (3); 370.1—pollen (3); 370.12—coffee bean (1); 370.51—corn dust (1); 371.00—flour NOS (3); 371.04—wheat flour (2); 371.06—cornstarch (1); 373.07—Mahogany (1); 373.24—tropical hardwood NOS (1).

exposure categories are "miscellaneous chemicals and materials, referenced by use" (31%); followed by "mineral and inorganic dusts" (12%) and "plant materials" (11%) (Table 5). Washington's third largest exposure source, "plant material" is not included among the SENSOR states top 10 exposure sources (one component, "wood dust, NOS" ranks 27th). Washington differs from the four SENSOR states in that plant materials are a predominant asthma-causing exposure in our population. This difference may be an argument for expanding WRA surveillance into more states, so that it could be more representative of regional differences in industries and exposure.

Another difference in Washington State data is our reported percentage of NOA compared to WAA, which in our data was 55% NOA (of which one in five were cases of RADS) and 44% WAA; another study (22) cited SENSOR results of 19.1% WAA and another case series as having 27% WAA. A study of physician-reported cases of WRA in CA found 65.3% NOA (with 6.1% RADS) and 34.7% WAA (10). Our results had a slightly higher percentage of WAA compared with those previously reported estimates; however, other cited estimates of WAA (23) from a variety of studies from the United States and Canada found numbers ranging from 6% to 50% and a more recent review of studies of work-exacerbated asthma (WEA) reported a range from 36% to 58% of all WRA cases were WEA (24) and our results fall within this range.

Results from SENSOR asthma surveillance in four states from 1993 to 2002 reported 20% WAA, 68% NOA, and 9% RADS (9), although the percentages varied by state with CA reporting the highest percentage of WAA, 30%. We report 11% classified as RADS here, and this is slightly higher than what was reported in the SENSOR results.

For noncompensable claims, the median claim costs were not significantly higher for plant material claims than claims with other exposure sources. Because they can cost more in both claim costs and days of time loss, reducing the number of these claims through prevention would be beneficial both for workers and employers.

Western Red Cedar has long been recognized with occupational asthma (25–27); the asthma is caused by the plicatic acid (28) in the wood. In the medical records and follow-up interviews, injured workers noted that the quality of sawdust can vary by the type and age of the wood handled. Older and drier stockpiled logs were noted to give off finer, lighter dust whereas green logs were associated with a heavier, wetter sawdust.

While many injured workers reported cutting and sanding wood, illness was not limited to those handling the wood directly. Approximately 10 cases were from secondary exposure to wood dust when it migrated into their work area or by workers responsible for cleaning or transporting wood waste. In one manufacturing industry case, a hot tub assembler was exposed to cedar dust that had been generated upstream in the process during cutting and sanding. In this case, assembly workers had not been included in the respiratory program. That secondary exposure to cedar dust can cause illness which underscores the need for proper ventilation at the point of operation and segregation of processes. In secondary wood manufacturing, all workers should be evaluated for their exposure to wood dust.

Another notable plant material in the Pacific Northwest is the Hop plant. Hops (*Humulus lupulus*) are plants whose female flower clusters are used primarily in the brewing of beer. According to hop growers of United States, Washington's Yakima Valley holds 75% of all US hops acreage and it is grown on small third- and fourth-generation family farms (29). Hops production is labor intensive and requires a variety of manual handling tasks such as winding hops plants during the growing season, and drying and baling during harvest that can expose workers to hop dust. Many of these activities produce fine hop dust, and workers are exposed to dust in a variety of tasks including field work, loading hops onto trucks and conveyor belts, processing (moving, drying, baling, extracting, etc.), and cleaning. One of the hops cases reported here was for a maintenance worker exposed to hop dust within the processing machinery that he was responsible for repairing.

There have been case reports of work-related respiratory disease to hops in the European literature as early as 1978 through 2002 (16, 30, 31). In 2004, Góra et al. found that the dust, microorganisms, and endotoxin concentrations measured in hop farmers were relatively low compared to similar exposures in herb processing, grain handling, and poultry, cattle and pig farming (32). The lower microbial concentrations are hypothesized to be due, in part, to the antimicrobial properties of the hops plant (32, 33). While hops farmer's microbiological exposures may be lower than other types of agriculture, Góra et al. found that the prevalence of work-related respiratory symptoms in hops farmers was similar to pig farmers and grain-handling farmers (32).

The data presented here are likely to be underestimate of the true burden of WRA in Washington State. Asthma claims are brought into the surveillance system based on text word search. Therefore, claims with no (blank) text information or claims with no mention of "asthma" (including possible misspellings) on the RIIOD form are not included. Workers employed by a self-insured employer may not be included (they often lack complete information). Workers who voluntarily seek alternative employment, away from their asthma-causing source, are unlikely to seek medical diagnoses or file a claim once they begin to feel better. Asthma is generally accepted as an illness that is poorly recognized by injured workers and poorly diagnosed by healthcare providers as being potentially work-related in origin, and this likely leads to an underestimation of the number of WRA cases.

It is possible that these cases are mischaracterized as asthma by the healthcare provider. An organic dust toxic syndrome can result after inhalation of agricultural organic dusts. Other possible allergens or irritants on wood or agricultural products, such as molds and

endotoxins, may be responsible for the development of respiratory sensitization or irritation. However, regardless of the precise etiology, reducing exposure to these plant materials is feasible and would likely reduce the number of asthma or asthma-like respiratory problems in workers, and the associated costs.

Conclusion

WRA is a serious issue—common, costly, and a significant public health burden. Exposure sources are numerous and varied and Washington State appears to have more cases of asthma caused by plant materials compared to other US states conducting occupational asthma surveillance. Prevention of occupational asthma in Washington requires a focus on exposures from plant materials such as Western Red Cedar and hops. The regional differences in asthma-causing agents compared to other US states illustrate the importance and value of regionally based asthma surveillance.

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Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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