The Association between Occupational Toxic Inhalation Injuries to Cleaning and Disinfectant Exposures and the COVID-19 Pandemic in Washington State's Workers' Compensation Claim Database

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Abstract

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Background: Within six weeks of the first case of COVID-19 in early Dec 2019 in Wuhan, China, the pandemic had already a foothold half-way around the world in Washington State, where the the first case of COVID-19 in the United States was confirmed on 20 Jan 2020 in a traveler returning from the index city. A number of public health measures were instituted in the US to counter the spread of disease, to include the intensified use of cleaning chemicals and disinfectants to prevent the spread of SARS-CoV-2 virus. With the increased use of and exposure to such chemicals comes the commensurate risk of increased toxic inhalation injury incidence, as suggested by US and Canadian national poison control center surveillance data, comparing the number of calls made to poison centers before and during the COVID-19. However, these data did not differentiate non-occupational from occupational exposures, the latter of which might result in greater exposures, more serious injury and a higher economic burden. Based on these and similar studies and public health recommendations and policies

that likely resulted in increased exposure to cleaners and disinfectants, we hypothesized that workers in Washington State may have experienced an increase in toxic inhalation injuries and work-related asthma due to cleaners and disinfectants during the COVID-19 pandemic.

Methods: We conducted a retrospective cohort study of Washington State workers' compensation (WC) claims filed between 2017 and 2022 to assess the temporal relationship between claims filed for toxic inhalation and work-related asthma to cleaning and disinfectant agents and the COVID-19 pandemic. Data elements included chemical exposure, occupational, and industry codes; sex and age of worker on date of injury; date and calendar quarter of injury; claim status; if a claim involved hospitalization, disability, or fatality; time-loss days; claim costs. Descriptive statistics were tabulated both by era and by quarter. Using full-time equivalent (FTE) data and total quantity of WC claims information by quarter, incidence rates between the pre-pandemic and pandemic groups were calculated, and a statistical analysis of the incidence rate ratios or incidence risk ratios was performed, using the two-sample inference for incidence-rate and chi-squared test of differences in proportions, respectively.

Results: Surveillance data identified 486 unique WC claims involving inhalational exposures to cleaners and disinfectants out of 798,436 total WC claims. The pre-pandemic era comprised 12 quarters within the period 1 Jan 2017 – 31 Dec 2019 with 295 claims, and the pandemic era comprised 10 quarters within the period 1 Jan 2020 – 31 Mar 2022 with 191 claims. When comparing the pandemic era with pre-pandemic era, the incidence rate of cleaner-disinfectant inhalational claims based on total FTE decreased 21% from 4.2 per 100,000 FTE to 3.3 per 100,000 FTE (IRR 0.79, 95% CI 0.66 – 0.95, $p = 0.013$). Incidence risk based on total workers' compensation claims decreased by 11% from 6.4 per 10,000 to 5.7 per 10,000 (IRR 0.89, 95% CI 0.74 – 1.07, $p = 0.22$). Incidence risk based on total toxic inhalation claims increased by 27% from 0.13 to 0.16 (IRR 1.27, 95% CI 1.07 – 1.50, $p = 0.007$). When

comparing the first quarter of the pandemic against the same quarter in the preceding year, the incidence rate of cleaner-disinfectant inhalational claims based on total FTE increased by 76% from 3.90 per 100,000 FTE to 6.85 per 100,000 FTE (IRR 1.76, 95% CI 1.04 – 2.96, p = 0.032). Incidence risk based on total workers' compensation claims increased by 84% from 6.1 per 10,000 to 11.3 per 10,000 (IRR 1.84, 95% CI 1.09 – 3.10, p = 0.020). Incidence risk based on total toxic inhalation claims increased by 58% from 0.12 to 0.19 (IRR 1.58, 95% CI 0.96 – 2.59, p = 0.066). Descriptive statistics indicated that some occupations filed proportionately more claims in the pandemic era than in the pre-pandemic era (Management, Sales and Related, Construction and Extraction, Transportation and Material Moving) while other occupations filed proportionately fewer claims (Food Preparation and Serving Related, Personal Care and Services); some industries filed proportionately more claims in the pandemic era than in the pre-pandemic era (Retail trade, Transportation and Warehousing, Educational Services).

Conclusions: These results indicate an increase in inhalational occupational exposures and injuries to cleaning and disinfectant chemicals in the early phases of the COVID-19 pandemic in Washington State, consistent with trends seen in previous studies. Review of claims records corroborate a number of contributing factors, such as hazardous application methods and inadequate hierarchy of controls. Continuing occupational surveillance and efforts to identify root causes for toxic inhalation injuries are critical to informing future public health policies and organizational procedures surrounding the safe use of cleaning and disinfecting agents, balanced with the public health promoting activities of cleaning and disinfection of the workplace.

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ACKNOWLEDGEMENTS

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INTRODUCTION AND BACKGROUND

The first cases of COVID-19 occurred in early Dec 2019 as a yet unidentified respiratory illness in the city of Wuhan in Hubei province, China - after similar cases accrued quickly, local physicians, witnessing evidence of human-to-human transmission, expressed concern to higher authorities who delayed acknowledging the outbreak until 9 Jan 2020 (*1,2*). Even then, the government continued to downplay human transmissibility, only reversing its stance on 21 Jan 2020, soon after which it ordered the lockdown of Wuhan, where cases had now grown to 444, and several other cities on 23 Jan 2020 (*1-3*). But this lockdown came too late to halt or delay the international spread. And although the Wuhan Institute of Virology had genetically sequenced what would be known as the SARS-CoV-2 virus as soon as 2 Jan 2020, the genome wasn't shared publicly with the international community until 11 Jan 2020, further contributing to delayed diagnosis and spread of disease erupting globally, to include the United States, in which the first case of COVID-19, in a returning traveler who had been in Wuhan, was confirmed on 20 Jan 2020 in Washington State (*1,2*). On 31 Jan 2020, the World Health Organization (WHO) declared the coronavirus outbreak a Public Health Emergency of International Concern (*2*). Over the next several weeks, cases from travelers returning to the US from China or elsewhere increased, but by Mar 2020, numbers of domestic transmission cases were growing over those of imported ones (*4*). By 11 Mar 2020, the WHO declared COVID-19 a pandemic, with over 1900 cases in the US and 118,000 cases in 114 countries (*2,5*).

Major sources for US domestic transmissions involved professional and social events and gatherings, high-risk congregate settings such as skilled and long-term care facilities and other workplaces; factors contributing to transmission included limitations in testing for screening and diagnostics and presymptomatic/asymptomatic spread of infection. Initial measures involved traveler screening, restrictions, quarantine/isolation and restrictions on travel. But as cases involving workplace, congregate settings, and presymptomatic/asymptomatic spread became more prominent, control

measures were adapted accordingly - e.g., social distancing, face mask/PPE guidance, telework, shutdown of schools, businesses, mass gatherings, and environmental infection control guidance (*4*).

After both the first case of COVID-19 in the US and the first death were confirmed to have occurred in Washington State on January 20, 2020 and February 29, 2020 respectively, measures to prevent the spread of SARS-CoV-2 intensified, to include the use of cleaning chemicals and disinfectants (*6-8*).

For example, by late Mar 2020 at the start of the pandemic, the CDC issued infection prevention recommendations to households, such as frequent hand hygiene, avoiding close contact with sick people, social distancing, staying at home if feeling sick, covering coughs and sneezes, wearing facemasks, and cleaning and disinfecting frequently touched surfaces daily with bleach, alcohol solutions, or EPA-registered household disinfectants effective against emerging viral pathogens (*9*).

CDC infection control recommendations for healthcare settings included a number of administrative controls, engineering controls, use of PPE, training and education of personnel, and implementation of environmental infection controls such as cleaning and disinfection (with EPA-registered List N disinfectants) procedures to minimize exposures to healthcare personnel (*10*).

Infection control recommendations to non-healthcare facilities (e.g., schools, offices, daycare centers, businesses, community centers) were focused on cleaning and disinfection of areas exposed to suspected or confirmed cases of COVID-19 and included administrative controls, use of PPE, and environmental infection control procedures such as cleaning (with detergent, or soap/water) and disinfecting offices, bathrooms, common areas, shared equipment, and other high-touch surfaces and objects with EPA-registered household disinfectants (*11*).

The CDC issued guidance for cleaning and disinfecting practices for correctional facilities, advising more frequent and expanded use of cleaners and EPA-registered disinfectants on high-touch surfaces and objects, even those not ordinarily cleaned daily, lifting restrictions on use of undiluted

disinfectants if necessary, and training additional staff and incarcerated personnel to perform cleaning and disinfecting of the facilities (*12*).

The US Environmental Protection Agency defines cleaning products as soaps and detergents that remove dirt and organic matter from surfaces to reduce microbial load and improve disinfectant efficacy, sanitizing products as chemicals that kill bacteria on surfaces, and disinfecting products as chemicals that kill viruses and bacteria on surfaces (*13*). The US Centers for Disease Control and Prevention outlines best practices for the safe and effective use of cleaning and disinfecting chemicals (*14*). But cleaning chemicals and disinfectants have been increasingly recognized to be epidemiologically associated with work-related asthma. In a review of studies from 2004 to 2019, health workers, who are exposed to a range of chemical products (sensitizers and irritants) to clean and disinfect instruments, fixed surfaces, and skin and wounds, are estimated to have an asthma prevalence from 4.4% to 11.2% (*15*). In a meta-analysis of 24 studies, occupational cleaners were found to have a 50% increased risk of WRA and a 43% increased risk of chronic obstructive pulmonary disease (*16*).

Toxic inhalation (TI) exposures to cleaner-disinfectants may result in toxic inhalation injuries or work-related asthma.

Toxic inhalation injuries to the upper airway may be acute (edema of the nasopharynx and larynx to epithelial ulceration and frank hemorrhage, reflex bronchospasm, laryngospasm, laryngitis, tracheobronchitis) or chronic (chronic rhinitis, laryngeal polyps); injuries to the conducting airways may be acute (edema, inflammation, and bronchoconstriction, bronchospasm) or chronic (reactive airways dysfunction syndrome, bronchiectasis, chronic obstructive pulmonary disease, vocal cord dysfunction); and injuries to the lower airways and pulmonary parenchyma may be acute (inhalation fever, pulmonary edema, adult respiratory distress syndrome) or chronic (bronchiolitis obliterans, cryptogenic organizing pneumonia, hypersensitivity pneumonitis) (*17,18*).

Work-related asthma (WRA) can be caused by either toxic (cleaner-disinfectants or other categories of toxic substances) or non-toxic inhalational exposure. It is the most common occupational lung disease, with an estimated global population attributable fraction of 16%, incidence of 3-36%, and, among adult-onset asthma cases, a prevalence of 15-20% (*19,20*). Work-related asthma encompasses (1) occupational asthma (OA) and (2) work-aggravated or work-exacerbated asthma (WAA or WEA – comprising 10-50% of WRA cases), in which preexisting asthma is aggravated by workplace exposures to (*20,21*). Toxic inhalation exposures from cleaner-disinfectants may be associated with either type of WRA.

Cleaning chemicals include ingredients such as detergents (fatty acid salts, organic sulphonates), alkaline agents to dissolve fatty acids (sodium hydroxide, ammonia, silicates, carbonates), acids (phosphoric, acetic, citric, sulphamic, hydrochloric), water softeners (tripolyphosphates, EDTA), solvents (alcohols, glycol ethers), corrosion inhibitors (monoethanolamines), and preservatives (benzalkonium chloride, isothiazolinones, formaldehyde) (*22*).

The EPA manages registration of disinfectants under alphabetical lists specific for certain capabilities: those assigned to List N are approved for use against the COVID-19 virus. The list has grown from 82 products at the beginning of the pandemic to over 600 as of Apr 2023, covering 36 unique chemical ingredients, comprising major classes such as alcohols, phenols, chlorine-releasing, ammonium, quaternary ammonium compounds (QAC), acids, and peroxides, in 58 different combinations of one to several of these ingredients. Nearly 300 come in a concentrated form that may require dilution, and seven come in a form for fogging, misting, vapor, and gas applications (*23*).

Cleaners and disinfectants cause general effects of irritation and sensitization to mucous membranes and skin, resulting in cellular and tissue inflammatory reactions (*22*). In toxic inhalation, the effects are localized along the upper or lower respiratory tract, depend on the solubility of the chemical, where more soluble ones such as ammonia react in the upper airways, while less soluble ones such as

solvents, pass all the way to the terminal bronchioles and alveoli where their effects predominate (*24*). Some possible mechanisms triggering inflammation are sensory irritation through stimulation of afferent nerves and tissue irritation in which epithelia are directly injured, exposing underlying nerves, muscles, blood vessels (*17,24*).

The COVID-19 cleaning and disinfection procedures recommended or mandated by public health and governmental organizations may have increased exposure to cleaning and disinfecting chemicals not only in occupations, industries, or households where such chemicals were normally used but also in those where such chemicals were infrequently or never used, with additional risks of improper preparation/usage and inadequate implementation of hierarchy of controls such as ventilation and personal protective equipment. Studies from national poison control center data found that more calls were made about exposures to cleaners and disinfectants in the beginning months of the COVID-19 pandemic in 2020 compared to the same period of the years preceding the pandemic, suggesting this was the indeed the case. One of these described a 16.4% - 20.4% increase in US poison center calls received from January to March in 2020 compared with the same period in 2019 and 2018, with bleaches making up 62.1% of the cleaner increase and nonalcohol disinfectants making up 36.7% of the disinfectant increase (*8*). Another study of Canadian poison center data described a 35% increase in total exposures when comparing January 2020 to January 2019 followed by a more heterogeneous increase in the following months, depending on the particular cleaning and disinfectant exposure categories (*25*). These studies have several notable limitations, including incomplete case capture and self-reported exposures and symptoms, which may have contributed to substantial misclassification (*8, 25*). Importantly, these prior studies do not differentiate occupational from non-occupational exposures, which may result in greater exposures, more serious injury and a higher economic burden.

Based on these and similar studies and public health recommendations and policies that may have resulted in increased exposure to cleaners and disinfectants, we hypothesized that workers in

Washington State may have experienced an increase in toxic inhalation injuries (TII) and WRA due to cleaners and disinfectants during the COVID-19 pandemic. To explore this hypothesis, we conducted a retrospective cohort study of Washington State workers' compensation (WC) claims filed between 2017 and 2022 to assess the temporal relationship between claims filed for toxic inhalation and work-related asthma to cleaning and disinfectant agents and the COVID-19 pandemic. Identifying causes for increased number of toxic inhalation injuries will help inform future public health policies and regulations and organizational procedures and guidelines for training in use and application of cleaning and disinfecting agents, implementation of a hierarchy of controls, and medical/occupational surveillance to improve primary and secondary prevention of death, disease, injury, and other adverse health outcomes in workers, balanced with the public health promoting activities of cleaning and disinfection of the workplace.

METHODS

Data source

The data for this study comes from Washington State Department of Labor & Industries (WA L&I) workers' compensation claims system. Washington is one of four states that administers its workers' compensation program through (1) a state fund to which 99.7% of employers contribute, covering two-third of workers (~1.9 million) in the state, or (2) self-insured employers, who use their own funds to provide benefits (*26,27*). A small percentage of workers are covered under other compensation schemes or fall under employers exempt from carrying mandatory state insurance (notably, federal employees covered under the Federal Employees' Compensation Act) (*26,28*). Since the circumstances and medical information supporting a State Fund claim for a workplace injury must be submitted to L&I for review, the centralized state's workers' compensation system provides an opportunity to capture and study a majority of the occupational illnesses and injuries occurring in the state. Self-insured employers may also share claims documentation for workplace injuries with L&I, but these will be of more limited scope and more administrative than medical in content, since claims are not adjudicated by L&I (*29*).

Under L&I, the SHARP (Safety & Health Assessment & Research for Prevention) program performs research to inform efforts to improve workplace safety through prevention of workplace injuries and illnesses. SHARP performs ongoing occupational health surveillance of trends, diseases and injuries, high-risk industries and exposures under several programs, two of which – occupational respiratory disease (ORD) and toxic inhalation (TI) – provided data for this study (*30*). The ORD surveillance program monitors for medical conditions of work-related asthma, asbestos-related disease, silicosis, Valley fever, and chronic obstructive pulmonary disease, but for the purposes of this study, only WRA data was retained for evaluation (*27*). The TI surveillance program monitors for workplace exposures rather than medical conditions – namely, to eight priority substances of epidemiological

importance (ammonia, beryllium, carbon monoxide, chlorine, chromium, metal fume, methylene chloride, and wildland smoke) and to a non-specific category of chemicals, metals, vapors, gases, dusts, or fumes of interest – for this study, only cleaner and disinfectant exposures were retained for evaluation (*31*).

The primary data source for both programs come from the L&I WC claims data warehouse which is queried monthly for claims from both state- and self-insured employers. Health care provider/facility reports for work-related asthma, a mandatory notifiable condition, provide additional data to the ORD program only. The primary documentation of interest housed in the data warehouse are the 1) Report of Industrial Injury or Occupational Disease (RIIOD) form, completed by the injured worker and the treating physician, which is filed with all claims, describes the injuries sustained and initial medical diagnoses, 2) outpatient/inpatient medical and other health records, 3) billing records, 4) correspondence submitted to L&I in support of each claim by health care providers, patients, employers discussing diagnoses or exposures. Potential cases for ORD and TI surveillance programs are captured by manual review by searching for 1) keywords, narrative text, 2) International Classification of Disease, Tenth Revision, Clinical Modification (ICD-10-CM) codes assigned by providers, and 3) Occupational Injury and Illness Classification System (OIICS) codes assigned by L&I insurance staff. Cases meeting criteria as specified by the ORD and TI surveillance programs are entered into the ORD and/or TI surveillance databases as applicable (*27,31*).

Since the number of WC claims filed in any period of time is a function of the number of workers employed during that period of time, comparing the absolute number of claims is difficult to interpret unless adjusted for employment numbers. To establish incidence rates for claims and to adjust claim numbers to enable comparisons between different periods of time, quarterly full-time equivalent (FTE) worker data, subdivided by NAICS sector, was sourced from the Washington State Employment Security Department for the period from 1 Jan 2017 (beginning of first quarter 2017) through 30 Jun 2022 (end of

second quarter 2022). A typical FTE job defined as one that is equivalent to 8 hours/workday x 5 workdays/week x 13 weeks/quarter = 520 hours/quarter (*32*). To adjust respiratory WC claim information by the total number of all categories of WC claims filed in the periods of interest, the number of claims filed by quarter were extracted from the L&I WC claims system.

Study population

For this study, the ORD and TI data sets were combined, focusing on claims in which injuries occurred between 1 Jan 2017 and 30 Jun 2022 and claims with Association of Occupational and Environmental Clinic's (AOEC) exposure codes (discussed further below) specific for cleaners and disinfectants: 050.280 (disinfectants, NOS) and AOEC exposure codes 322.000 – 322.360 (encompassing 60 types of cleaning chemicals). The ORD and TI data sets identified the same 198 claims from the L&I data warehouse; the ORD data set identified 19 additional unique claims, and the TI data set identified another 269 unique claims.

Case definitions used for the ORD and TI surveillance programs

WRA Case Definition:

The definition for work-related asthma is the same as that of the National Institute for Occupational Safety and Health (NIOSH) Sentinel Event Notification System for Occupational Risks (SENSOR): diagnosis by a healthcare professional consistent with asthma and an association between symptoms of asthma and work. Cases are classified at 6 months of claim maturity; WRA is further categorized as WAA or new onset asthma (NOA), and NOA is sub-categorized as OA with latency or reactive airway dysfunction syndrome (RADS) (OA without latency) (*27*).

Patterns of work association may include the following: symptoms of asthma that develop or worsen after a worker starts a new job or after new materials are introduced on a job (a substantial

period can elapse between initial exposure and development of symptoms); symptoms that develop within minutes of specific activities or exposures at work; delayed symptoms that occur several hours after exposure (e.g., during the evenings of workdays); symptoms that occur less frequently or not at all on days away from work and on vacations; symptoms that occur more frequently when the affected worker returns to work; symptoms that are temporally associated with workplace exposure to an agent with irritant properties. Work-related changes in medication requirements can accompany these symptom patterns (*33*).

TI Case Definition:

A valid case is one involving known or suspected inhalation exposure to ammonia, beryllium, carbon monoxide, chlorine, chromium, metal fume, methylene chloride, wildland smoke or to a substance (chemical or metal, organic/inorganic, in the form of vapor, gas, dust, or fume) of particular epidemiological interest (*31*). Most cleaning and disinfecting substances not containing chlorine or ammonia fall under the "other" category.

Occupational exposure to cleaners and disinfectants

In both the ORD and TI data sets, workplace exposures are coded using the AOEC hierarchical exposure code system for chemical and non-chemical agents and includes information such as name of the substance, synonyms, Registry of Toxic Effects of Chemical Substances (RTECS) numbers and Chemical Abstracts Service (CAS) numbers. Each case is assigned between one and five codes (TI data set) or six codes (ORD data set), as a worker is often exposed to more than one substance (*27,31,34*). Claims with AOEC codes specific for cleaners and disinfectants include 050.280 (disinfectants, NOS) and AOEC exposure codes 322.000 – 322.360 (encompassing 60 types of cleaning chemicals).

Claims from the ORD data set were categorized into one of the three major classes of WRA: WAA, NOA, or RADS. Since the TI surveillance system was based on identifying exposures, the medical

diagnosis ultimately assigned to a claimant who sustained disease or injury from the workplace exposure was of secondary importance, so information obtained was variable – the outcome of importance was that an injury had occurred and that it was due to a workplace inhalational exposure.

Data elements such as occupation and industry derive from the workers' compensation administrative data. Occupation was coded using the 2002 Standard Occupational Classification (SOC) system, a hierarchical classification wherein each succeeding digit narrows the category (major group, minor group, broad group, detailed occupation). Industry was coded using the 2007 North American Industry Classification Coding System (NAICS), a two-through-six-digit hierarchical classification code system, wherein each digit in the code provides additional classification detail in narrower categories as follows: digits one and two designate the economic sector, digit three the subsector, digit four the industry group, digit five the NAICS industry, and digit six the national industry. If missing from the administrative data, industry and occupation were manually coded using employer information in the claim file (*31*). To simplify analysis, only the highest level or broadest category of occupation and industry classification assigned to a claim were utilized.

In addition, several SOC groups with low numbers of claims were combined as follows: SOC code 13 (Business and Financial Operations Occupations), 15 (Computer and Mathematical Occupations), 17 (Architecture and Engineering Occupations), 19 (Life, Physical, and Social Science Occupations), 21 (Community and Social Service Occupations), 23 (Legal Occupations), 25 (Educational Instruction and Library Occupations), 27 (Arts, Design, Entertainment, Sports, and Media Occupations), and 33 (Protective Service Occupations), were all grouped into 'Other Occupations'.

Several NAICS sectors with low numbers of claims were similarly combined as follows: NAICS codes 22 (Utilities), 23 (Construction), 42 (Wholesale Trade), 52 (Finance and Insurance), 53 (Real Estate Rental and Leasing), 54 Professional, Scientific, and Technical Services), and 71 (Arts, Entertainment, and Recreation), all grouped into 'Other Industries'. Several NAICS sectors representing the same sector

were combined as follows: NAICS codes 31 (Manufacturing), 32 (Manufacturing), and 33 (Manufacturing); NAICS codes 44 (Retail Trade) and 45 (Retail Trade); NAICS code 48 (Transportation and Warehousing) and 49 (Transportation and Warehousing).

Covariates

Additional claim data elements include sex and age of worker on date of injury; date and calendar quarter of injury; claim status (compensable, non-compensable, rejected, pending); if a claim involved hospitalization, disability, or fatality; number of days qualifying for time-loss compensation paid (received when a worker cannot work for >3 days following the date of injury); monetary cost of claims paid to worker.

A compensable claim is one in which payment is additionally made to compensate a worker who sustains injuries resulting in time loss, disability, or loss of earning power, in contrast to a non-compensable claim in which the injuries are not as severe to require such compensation. Rejected claims are those in which the workplace cannot be established as the proximate cause for injury or illness (*35*).

Statistical analysis

For this retrospective cohort study, the claims were divided into a pre-pandemic cohort of claims filed before the COVID-19 pandemic and a pandemic cohort of claims filed during the pandemic, the exposure being the pandemic and the outcome being the changes in cleaner-disinfectant exposures and injuries arising from this pandemic exposure. Although the WHO officially declared the pandemic on 11 Mar 2020 and the United States followed suit with a declaration of a nationwide emergency on 13 Mar 2020, prevention measures to counter the transmission of infection were already underway throughout the country, as the morbidity and mortality from COVID-19 were increasing every week

following the recognition of the first case of COVID-19 in Washington State on 20 Jan 2020 (*36,37*). Therefore, the first quarter of 2020 (1 Jan – 31 Mar 2020) was chosen for this study to mark the beginning of the pandemic and the division between pre- and pandemic claims.

Descriptive statistics were tabulated both by era and by quarter for number of workers by sex and the mean age on date of injury; number of compensable, non-compensable, rejected, or pending claims; number of hospitalizations, disability awards, or fatalities; number of claims with at least one day time-loss day; median cost of claims paid to workers; number of claims filed by occupation class; number of claims filed by industry sector.

Using FTE and total quantity of WC claims information by quarter, incidence rates between the pre-pandemic and pandemic groups were calculated, and a statistical analysis of the incidence rate ratios or incidence risk ratios was performed using the two-sample inference for incidence-rate and chi-squared test of differences in proportions respectively – results were considered statistically significant for $p < 0.05$. Because a number of industries in Washington State are known to experience seasonal and cyclical employment trends affecting employment, a subgroup analysis was performed in which groups in first quarter 2020 (first quarter of the pandemic) were compared with those from the first quarter of 2019 (same period in the year immediately preceding the pandemic) to control for seasonality (*38*). Based on trends in some studies where the greatest misuse/overuse to hazardous cleaners-disinfectants may have peaked before the third quarter of 2020, focusing on the riskiest periods of pandemic response might also provide greater precision of analysis (*25*).

All statistical analyses were performed using R version 4.3.0 (R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/). Study protocol, data, and systems access were approved by the Washington State Institutional Review Board.

RESULTS

Within the combined ORD and TI data sets, 486 unique WC claims out of 798,436 total WC claims were identified involving inhalational exposures to cleaners and disinfectants as classified by AOEC exposure code 050.280 and codes in the 322.xxx series. The full-time equivalent employee person-quarter coinciding to the quarters in which these claims arose was 128,140,000.

Table 1 summarizes the data within each of the pre-pandemic and the pandemic era. The pre-pandemic era comprised 12 quarters within the period 1 Jan 2017 – 31 Dec 2019 with 295 claims, and the pandemic era comprised 10 quarters within the period 1 Jan 2020 – 31 Mar 2022 with 191 claims. **Table 2** summarizes the data by calendar quarter for the year preceding the pandemic and the first year of the pandemic. **Table 3** summarizes the statistical analyses as discussed in subsequent paragraphs.

Claims filed in the pre-pandemic era constituted the unexposed cohort, while claims file in the pandemic era constituted the cohort hypothesized to be at greater risk of inhalational exposure to cleaners-disinfectants. To perform a statistical analysis between these two cohorts, three types of frequencies were estimated.

Incidence rates of cleaner-disinfectant inhalational claims

Incidence rates using total FTE as denominator: For the first estimate, the at-risk population from which claims might arise was derived from full-time equivalent data which served as an estimate of the number of workers in Washington State in each era, resulting in an incidence rate of 4.2 per 100,000 FTE and 3.3 per 100,000 FTE in the pre-pandemic and pandemic cohorts respectively, or a 21% decline (incidence rate ratio (IRR) 0.79, 95% Confidence Interval (CI) 0.66 – 0.95, p = 0.013). This stands in contrast to a 76% increase in incidence rates (IRR 1.76, 95% CI 1.04 – 2.96, p = 0.032) when comparing the first calendar quarter of the COVID-19 pandemic (1 Jan – 31 Mar 2020) to the same period of the

year preceding the pandemic (1 Jan – 31 Mar 2019), where the incidence rates were 5.6 per 100,000 FTE and 5.7 per 100,000 FTE, in the pre-pandemic and pandemic cohorts respectively (**Table 3**).

Incidence risks using total workers' compensation claims as the denominator: For the second estimate, the at-risk population from which inhalational claims might arise was derived from total WC claims in each era, resulting in an incidence risk of 6.4 per 10,000 and 5.7 per 10,000 in the pre-pandemic and pandemic cohorts respectively, for an incidence risk ratio of 0.89 (95% CI 0.74 – 1.07, p = 0.22). This 11% decline stands in contrast to a 84% increase in incidence risk (IRR 1.84, 95% CI 1.09 – 3.10, p = 0.020) when comparing the first quarters of 2019 and 2020, where the incidence risks were 6.1 per 10,000 and 11.3 per 10,000, in the pre-pandemic and pandemic cohorts respectively (**Table 3**).

Incidence risks using total inhalation claims (TI data set) as the denominator: For the third estimate, the at-risk population from which cleaner-disinfectant inhalational claims might arise was derived from total inhalational claims in each era. The proportions of toxic inhalations that were attributed to cleaning products were 0.13 and 0.16 in the pre-pandemic and pandemic cohorts respectively (IRR 1.27, 95% CI 1.07 – 1.50, p = 0.007). When comparing the first quarters of 2019 and 2020, the proportions were 0.12 and 0.19 in the pre-pandemic and pandemic cohorts respectively (IRR 1.58, 95% CI 0.96 – 2.59, p = 0.066) (**Table 3**).

A line chart for each of the above incidence rate and incidence risks by calendar quarter from 1 Jan 2017 to 31 Mar 2022 is provided in **Figure 1**, **Figure 2**, and **Figure 3**.

Descriptive statistics of claims data

The average number of valid TI and valid ORD claims filed per quarter in the pre-pandemic cohort was 24.6 times higher than the pandemic cohort's average of 19.0. The proportion of men was similar in both cohorts and slightly smaller than that of women; the average age was 39 and 41 years in

the pre-pandemic cohort and pandemic cohort respectively. About 90% of all claims were covered by the State Fund (**Table 1**).

Since workers might be exposed to several hazards simultaneously, some inhalational exposure claims were assigned multiple AOEC exposure codes. Of the 61 possible AOEC exposure codes, 37 were associated with the 486 claims. On average, there were 1.4 exposure codes assigned per claim in both cohorts. Three common subtypes of cleaning materials in widespread use – ammonia, bleach, and QAC – were selected for further scrutiny, the latter in particular for its known asthmagenic characteristics (*15,39*). The disinfectant class proportion was smaller in the pre-pandemic cohort than in the pandemic cohort (9% vs 26%) as well as cleaner sub-classes of QACs (3% vs 13%), whereas bleach was more prevalent in the pre-pandemic cohort (30% vs 22%) (**Table 1**).

Severity of the inhalational exposure was estimated based on medical outcomes (fatality, hospitalization, disability) and claims determinations (compensability status, time-loss days, claims costs paid to worker). Only one fatality was associated with the inhalational exposure to bleach in the workplace. However, medical records indicate he passed away from COVID-19 complications while hospitalized without mention of bleach as either a direct or indirect cause for death. Of the three hospitalizations, only one was actually linked to an occupational exposure to a cleaner-disinfectant – a pandemic cohort case in which a worker with history of severe asthma likely developed an exacerbation after inhalational exposure to a floor cleaning substance. There were slightly fewer disability (1% vs 2%), compensable claims (5% vs 13%), time loss days (4% vs 5%), and slightly lower median claim cost ($500 vs $1342) in the pre-pandemic cohort than in the pandemic cohort (**Table 1**).

Distribution of claims across occupational classes: On review of claims by occupation type in the pre-pandemic cohort, the SOC major classes represented most frequently included Building and Grounds Cleaning and Maintenance Occupations (21%), Food Preparation and Serving Related Occupations (13%), and Production Occupations (10%). During the COVID-19 pandemic, the SOC major

classes represented more frequently included Building and Grounds Cleaning and Maintenance Occupations (21%) and Transportation and Material Moving Occupations (18%) (**Table 1**). The occupations classes in which there was a 50% or greater change in claims submitted for toxic inhalations due to cleaning and disinfecting substances between eras are highlighted in **Figure 4:** in the pandemic era, proportionately more claims were filed by Management, Sales and Related, Construction and Extraction, and Transportation and Material Moving, while proportionately less claims were filed by Food Preparation and Serving Related, Personal Care and Services. **Figure 5** depicts the similar changes in proportion of claims, but for time periods restricted to pre-pandemic 2019 quarter 1 (Q1) and quarter 2 (Q2) vs pandemic 2020 Q1 and Q2.

Distribution of claims across industry sectors: On review of claims by industry type in the pre-pandemic cohort, the NAICS sectors represented more frequently included Health Care and Social Assistance (24%), Accommodation and Food Services (14%), and Manufacturing (13%). In the pandemic cohort, the NAICS sectors represented more frequently included Health Care and Social Assistance (18%), Retail Trade (13%), Education Services (11%) (**Table 1**). The industry sectors in which there was a 50% or greater change in claims submitted between eras are highlighted in **Figure 6:** in the pandemic era, proportionately more claims were filed by Retail trade, Transportation and Warehousing, and Educational Services. Of note, Educational Services includes the following health care organizations: University of Washington Medical Center and Harborview Medical Center. **Figure 7** depicts the similar changes in proportion of claims, but for time periods restricted to pre-pandemic 2019 Q1 and Q2 vs pandemic 2020 Q1 and Q2.

Case reports

Two clusters of cleaner-disinfectant exposures were identified that occurred in environments at high risk for SARS-CoV-2 transmission in Mar 2020, involving similar circumstances, exposures, and medical complaints.

In one cluster, four university health clinic employees (two administrators, two nurses, one nurse practitioner) complained of varying degrees of headache, nausea, nasal/pharyngeal irritation, shortness of breath, and chest tightness upon entering the clinic the day after it was treated (by either fogging, fumigation, or electrostatic spraying) by a cleaning company for disinfection after two patients had been in the seen in the clinic for suspected COVID-19. It was unclear which brand or chemical class of cleaner-disinfectant was used by the cleaning company. A fifth employee, a 36-year-old female administrator who had been absent from work during the fumigation and who had returned to the clinic 12 days after the disinfection, learned of the claims filed by her colleagues and subsequently presented to a hospital with similar symptoms. None of the employees required medical treatment, and no significant medical sequelae were documented in the claims records for any of them.

In another cluster, four bus drivers for a transit company reported varying symptoms of headache, nausea, eye irritation, sinus irritation, rhinorrhea, cough, difficulty breathing, chest congestion, rash that they attributed to inhalational exposure to an EPA-registered disinfectant containing sodium dichloroisocyanurate, that was applied by fumigation, fogging, or electrostatic spray, by the company in the buses they operated. Claim injury dates were within two weeks of each other. None of the employees required medical treatment, and no significant medical sequelae were documented in the claims records for any of them.

DISCUSSION

Washington had the distinction of being the very first state in which the pandemic secured a foothold, being the state in which the country's first COVID-19 case in Jan 2020 and first death in Feb 2020 were declared (*36,37*). Consequently, government and public health response occurred early and well in advance of the WHO declaration of the COVID-19 pandemic on 11 Mar 2020. The governor declared a state of emergency on 29 Feb 2020, and by early Mar 2020, schools began closing and companies began transitioning to remote work, followed by statewide mandatory closures of schools and restaurants, bars, and entertainment facilities by mid-Mar 2020, by which time the state department of health reported 74 deaths from 1300+ COVID-19 cases (*36,37*). The state economy nosedived in the months following the imposition of business restrictions and individual restriction of movement, bottoming out in May 2020 marked by a 16.3% unemployment rate, while WC claims filed for exposure to or disease from SARS-CoV-2 rose, with over 2400 filed by end of second quarter of 2020 (*38,40*).

In this retrospective study of Workers' Compensation claims in Washington State, we compared the incidence rates and incidence risks of cleaner-disinfectant toxic inhalation exposures and injuries in the pre-pandemic vs pandemic eras. When using FTE and total worker compensations claims, we surprisingly saw a decrease in incidence, contrary to our original hypothesis. However, when restricting our analysis to the first quarters of 2019 and 2020, we found these trends reversed. The occupations with the greatest shift in proportional burden of toxic inhalation exposures were those related to sales and transportation, while those with the least were those related to food preparation/serving-related and personal care/service. And the industries with the greatest shift in proportional burden of toxic inhalation exposures were those related to retail, transportation, and education, while those with the least were those related to manufacturing and accommodation/food service.

The TI-WRA incidence rate based on numbers of claims per general FTE, aggregated by era, unexpectedly decreased in the pandemic era by 21%. However, the assumptions underlying this analysis are likely oversimplified, as suggested by a closer examination of the economic and labor market trends preceding and during the pandemic in Washington State.

A number of industries are affected by seasonal variation across calendar months (e.g., weather, school, social/cultural/religious traditions), such as agriculture and related activities and scenic and sightseeing transportation, or event-driven business cycles across years, such as mining and oil and gas activities, resulting in corresponding changes in monthly employment (*41*). Such seasonal (bell-shaped increase/decrease every four quarters) and cyclical trends are observed in **Figure 8**. Therefore, the analysis restricted to the presumably more etiologically relevant time period of the first quarter of the pandemic and the corresponding quarter of the immediately preceding non-pandemic year likely provides a more accurate assessment of the effect of COVID-19-related cleaning and disinfection exposures on TI-WRA claims, in which case we see a 76% increase in the incidence rate ratio by FTE data.

In addition, the number of exposures may have been greatest only during the early response in the first two quarters of the pandemic at the height of uncertainty/unfamiliarity with proper and safe implementation of new cleaning-disinfection procedures recommended by public health and health care organizations. A Canadian study of cleaner-disinfectant exposure calls to the poison centers during the pandemic found that the percentage change in calls from the preceding year peaked at 250% and 150% in Apr 2020 for disinfectants and bleaches respectively, then decreased drastically to a 50% change from the preceding year by Jun 2020, possibly due to increased product use safety messaging by Canadian public health and government in reaction to these surveillance trends (*25*). As the pandemic unfolded, experimental, quantitative microbial risk assessment, and epidemiological studies of factors of transmission determined that fomite transmission of SARS-CoV-2 was low. This evidence may have

resulted in less intensive cleaning practices, with a subsequent reduction in occupational exposures and injuries to cleaning and disinfecting agents (*42*).

The TI-WRA incidence risk based on numbers of claims per general WC claims, aggregated by era, unexpectedly decreased in the pandemic era by 11% although this was not statistically significant. One issue with adjusting TI-WRA claims numbers over general WC claims is the large jump in the latter due to COVID-19 overshadowing the relatively fewer occupational TI exposures (**Figure 9**). According to SHARP's WC claims data, an average of 2100 claims for COVID-19 exposures and disease were submitted per quarter from 2020 Q2 to 2022 Q2, or an average of 6% of all WC claims per quarter (*40*). Nevertheless, when restricting analysis to the first quarters of 2019 and 2020, the incidence risk still manifested with a statistically significant increase of 84% in the pandemic quarter.

One of the primary variables affecting the number of TI-WRA claims is the industry's employment rate which fluctuates based on seasonal, structural, and cyclical factors, especially the significant cyclical effect of the COVID-19 pandemic which disproportionately curtailed certain sectors while boosting other sectors. For example, when comparing the percent change in employment, Oct 2019 – Oct 2020, the sectors in Leisure and Hospitality, Other Services, Manufacturing, Education and Health Services, Financial Activities, and Transportation, Warehousing and Utilities experienced drops from -2% to -20%, while the sectors in Information, Retail Trade, and Construction experienced positive growth (*38*).

A new variable arising from the pandemic was the move to remote and hybrid work which partially contributed to the increase in employment above. These industry sector numbers influence not only trends in the absolute number of exposures and claims (e.g., increased numbers of workers in the Information sector, compared with the Transportation sector, might increase the probability of exposure to cleaners-disinfectants in the Information sector, but this might be offset by a remote work environment where cleaners-disinfectants are less likely to be a significant exposure), but they also

complicate interpretation of existing claim data. When examining the claims for quarter 1 and 2 of 2020, health care/education and transportation businesses comprised 21% and 14% of claims, yet these industries were the ones with negative employment growth, suggesting a disproportionate burden of occupational exposure to cleaners-disinfectants (**Figure 7**). The Retail sector also experienced an increase in proportion of cases in 2020 compared with 2019 (**Figure 7**), and given the positive growth in this sector described above, this might represent a proportional risk in exposure with the rise in total number of workers.

The occupations that seem to have been affected by occupational exposures during the pandemic more than others are related to the industries affective above – namely, Sales and Related Occupations and Transportation and Material Moving Occupations (**Figure 5**).

In addition to the trends in occupations and industries, a descriptive analysis of cleaners and disinfectants associated with exposures suggests that more disinfectants were used in the pandemic era vs the pre-pandemic era (26% vs 9%) and specifically QAC disinfectants (13% vs 3%), potentially replacing bleach as the cleaner-disinfectant of choice, as proportion of bleach exposures decreased (22% vs 30%) (**Table 1**). Bleach and many other substances with the AOEC exposure code 322.xxx categories are not considered respiratory sensitizers, but QACs are known asthmagens, so the shift towards this chemical class might contribute to any increases in TI-WRA claims observed (*15,39*).

The two clusters of inhalational exposure serve as examples of the particular dangers of using fogging, fumigation, or electrostatic spray to apply disinfectants to surfaces in enclosed spaces. In the cluster of affected employees at a university health center clinic, claims documentation contain a statement by a supervisor which described a miscommunication on when it was safe to re-enter the building after completion of disinfection as well as inadequate ventilation of the clinic following the disinfection procedure. These administrative and technical errors ultimately lead to inhalational exposure by the employees who returned to the clinic spaces prematurely. In the case of the transit

company cluster, there was insufficient claims documentation to identify the root cause of the exposures.

The CDC makes no official recommendations on the use of these application methods, but it states that liquids, wipes, disinfectant sprays are often sufficient to accomplish cleaning and disinfection tasks, and that only special circumstances warrant use of sprayers, foggers, or vaporizers, such as need for rapid disinfection to quickly render an area for safe use by occupants or to disinfect surfaces hard to reach by any other method. It warns of the increased risks of eye, skin, and airway irritation injuries of such aerosolized products and stresses the need to exercise extreme caution to ensure safety (e.g., use by trained professionals only with proper PPE, compliance with manufacturers' instructions, clearing area to prevent exposure to bystanders, removing residue per directions) (*43*). The WHO on the other hand recommends against using electrostatic sprayers, foggers, vaporizers, citing problems with efficacy (e.g., contacting the entire surface for the required contact time, failure to treat areas not in the direct spray zone), incompletely decontaminating surfaces that have not been cleaned first, and health risks mentioned above (*44*). Because of the increased probability of a COVID-19 case coming into contact with a university health clinic or a city bus and the concerns for infecting vulnerable populations and/or large number of people sharing these spaces, these environments were likely considered especially high risk. Given the theoretical risk of fomite transmission in the early stages of the pandemic, disinfection practices and protocols that would otherwise have never been adopted were nonetheless adopted at a time of heightened uncertainty.

To address some of the limitations with FTE data and general WC claims data above, the TI-WRA incidence risk was calculated based on a restricted subset of claims arising from all TI exposures only (eight priority and an "other" substances described in the Methods section). As in the above analyses comparing data in the presumed etiologically relevant first quarters of 2019 and 2020, the incidence risk of cleaner-disinfectant exposures increased significantly by 58% in the pandemic era, although this was

not statistically significant. However, in contrast to the previous analyses, the incidence risk also increased significantly by 27% when examining aggregated data by era, suggesting ongoing exposures through at least quarter 2 of 2022 (**Table 4**).

One of the primary advantages of this study is the capture of occupational exposures and injuries data for a large majority – approximately two-thirds – of workers in Washington State covered by the State Fund insurance claims. One of the limitations is the incomplete capture of data for workers under self-insured employers. Although WA L&I reviews self-insured claims, it does so in an administrative oversight role to ensure compliance with state worker's compensation laws – it does not adjudicate self-insured claims, a process in which medical records would be carefully reviewed to ascertain the connection between injury and workplace (*29,45*). Consequently, the exposure and injury data available for our review might not be as robust in self-insured claim filings compared to the medical records available for review through the State Fund. The principal health care systems in Washington State – MultiCare, Swedish, Virginia Mason Franciscan Health, Kaiser Permanente – are all self-insured (*46*). Since cleaners-disinfectants are widely used in the Health Care and Social Assistance industry sector and by Healthcare Support and Healthcare Practitioners and Technical major occupation groups, it is unknown to what extent exposure and injury data are adequately captured from the above health care systems, potentially resulting in an underestimate of exposures and injuries. Alternatively, it's possible that this data could be extrapolated from the two health care organizations that are covered by the State Fund, University of Washington Medical Center and Harborview Medical Center, to estimate effects on healthcare workers throughout the state. Another notable, though small, category of workers not captured by the state WC system is that covering federal employees who comprise 2.2% of nonfarm employees in the state (*47*).

Another limitation is the inability to ascertain the actual exposure of workers and the true incidence of disease and injury. The pre-exposure cohort (pre-pandemic era) and post-exposure cohort

(pandemic era) were sampled from a pool of workers who were already injured and exposed, and the analysis could only compare changes in rates between the two cohorts, classifying the COVID-19 pandemic as an exposure in a more abstract sense. In addition, a major drawback is the absence of a control group to understand the counterfactual, such as in a difference-in-difference quasi-experimental study, of what the trend in incidence rates and risks would have been in the absence of pandemic – the irregular pattern of incidence rates and proportions prior to the pandemic (**Figure 1**, **Figure 2**, **Figure 3**) suggest the necessity for such a counterfactual to adjust for temporal variations. Was the observed increase in incidence in 2020 actually due to the pandemic, or would the increase have occurred even in the absence of the pandemic? Consequently, no causality can be attributed from the statistical inferences performed in this study.

The study is also susceptible to several forms of bias, such as selection bias. A no-fault industrial insurance system lowers the barriers for workers to seek health care for workplace injuries, and in some cases, workers may have more of an incentive to file a claim for benefits even when injuries and exposures are not clearly associated with the workplace. For example, in the university health clinic cluster, one of the claimants, who returned to the clinic for the first time after its fumigation, reported symptoms, even though it had been almost two weeks since the fumigation, by which time it was unlikely there was any residual disinfectant remaining. As she was aware of complaints filed by her co-workers, there is a possibility of selection bias in this instance. On the other hand, the insurance system might discourage other workers (undocumented immigration status, non-English speaking, uninformed about workers' rights and WC system) from filing claims, and workers with minor or self-limited symptoms might not bother to file a claim, causing an underestimate of exposures and injuries in certain populations (*31*).

Another form of bias is information bias arising from misclassification of disease and injury, probably non-differential given that there isn't any reason to suspect a difference in diagnostic

reasoning before or during the pandemic. Non-specific symptoms such as those mentioned in the cluster cases above lack objective testing to verify. In addition, many of these workers are not evaluated by a healthcare provider specializing in occupational medicine, so objective evidence and medical documentation is often lacking to identify an exposure and prove a disease or injury, with the workplace as the proximate cause. However, restricting the data sets to only those in which claims were compensable (injuries linked to the workplace) would severely limit any analysis of workplace exposures and injuries.

Information bias also affects data collection: the searches of keywords, ICD-10-CM codes (over 500 being associated with the 486 claims), and review of narrative text in a multitude of scanned documents in the claims data warehouse are made difficult by lack of digital documentation and a formal occupational health records system. For example, while spot-checking the data, several instances of non-inhalational injuries misclassified as inhalational were discovered. No doubt, cases of inhalational injuries/exposure were also misclassified as non-inhalational. As mentioned in the Results section, cases of hospitalization associated with a TI-WRA claim appeared to be incidental to an unrelated cause, but they were flagged as occupationally-related since medical records were sometimes sent in mass, resulting in a mix of work and non-work records sent to WA L&I.

AOEC exposure code assignment is also subject to bias – for example, in the bus driver cluster, all workers were exposed to the same disinfectant – three were assigned AOEC EC 050.280 (Disinfectants, NOS), while the fourth was assigned 322.190 (Cleaners, Disinfectant, NOS). It can be challenging to not only identify the proper cleaner-disinfectant from the RIIOD and medical history, assuming it is reported at all, but to also correctly classify one of hundreds of cleaning or disinfectant products (some of which contain multiple active ingredients) into one of the hundreds of AOEC exposure codes. The boundaries between cleaners and disinfectants are also sometimes uncertain. In this study,

we searched for 61 different AOEC codes, but other studies of occupational exposure to cleaners and disinfectants have expanded the definition to include up to 115 AOEC exposure codes (*48*).

Despite the limitations, the available WC claims data compiled from the WA L&I data warehouse have provided important insight into the occupational inhalational exposures and injuries to cleaners and disinfectants and their trends during the COVID-19 pandemic in Washington State – no comparable data sets exist. Analyses are consistent with trends seen in other studies (*8,25,49*). Review of RIIOD and medical records corroborate that injury occurs due to improper preparation, mixing, application/use, inadequate ventilation, improper or inadequate PPE, improper hierarchy of controls. These exposures and injuries affect not only workers applying the products but also workers who are bystanders and incidentally exposed. Cleaning and disinfection are critical public health measures to counter transmission of COVID-19 or any other infectious disease epidemic that will invariably arise in the future. But mitigating the spread of disease requires mitigation of inadvertent, yet preventable, injuries arising from countermeasures. Meanwhile, ongoing surveillance efforts are critical to ensuring the safety and health of workers, especially during times of uncertainty. Future efforts to improve understanding the relationship between exposure and injury/disease, to include effect modifiers and confounders, would ideally examine the role of medical comorbidities (e.g., asthma, chronic obstructive pulmonary disease, allergy, atopy, smoking history) and quantify exposures (dosage, concentration, frequency).

Table 1. Washington State workers' compensation claims from toxic inhalation injuries and work-related asthma due to cleaning and disinfecting substances, 1 Jan 2017 - 30 Jun 2022.

	Pre-pandemic era (1 Jan 2017 – 31 Dec 2019)		**Pandemic era (1 Jan 2020 – 30 Jun 2022)**	
Descriptive statistics				
Total, n	295		191	
Mean per quarter, M (SD)	24.6	(6.47)	19.1	(8.76)
Total/FTE[a], per 100,000 FTE	4.177		3.321	
Total/general WC claims[b], per 10,000 claims	6.38		5.69	
Total/TI WC claims (TI surveillance data only)[c]	0.128		0.162	
Sex				
Male, n (%)	131	(44%)	76	(40%)
Age				
Mean per quarter, M (SD)	39.47	(14.47)	41.46	(13.96)
Insurance type				
State fund, n (%)	274	(92.9%)	171	(89.5%)
Self-insured, n (%)	21	(7.1%)	20	(10.5%)
Exposure (AOEC exposure code), n (%)[d]				
All disinfectants and cleaning materials (050.280, 322.xxx)	427	(100%)	267	(100%)
Disinfectants (050.280 and 322.190)	37	(9%)	69	(26%)
Cleaning materials (322.xxx, excluding 322.190)	390	(91%)	198	(74%)
Ammonia (322.070/090)	9	(2%)	3	(1%)
Bleach (322.100/110/120/130)	126	(30%)	60	(22%)
Quaternary ammonium compounds (322.32x)	11	(3%)	35	(13%)
Severity, n				
Fatality	0	(0%)	1	(1%)
Hospitalization	2	(1%)	1	(1%)
Disability award	3	(1%)	4	(1%)
Compensability status				
Compensable	15	(5%)	25	(13%)
Non-compensable	186	(63%)	86	(45%)
Rejected	86	(29%)	71	(37%)
Pending	8	(3%)	9	(5%)
Claims with >= 1 time-loss day, n (% of claims)[e]	12	(4%)	15	(5%)
Claim cost $, Mdn (IQR)[f]	500	(351, 950)	1,342	(409, 1752)
Occupation, SOC, n (%)				
Other (13, 15, 17, 19, 21, 23, 25, 27, 33)[g]	14	(5%)	15	(8%)
11 Management	5	(2%)	8	(4%)

29 Healthcare Practitioners and Technical	21	(7%)	9	(5%)
31 Healthcare Support	12	(4%)	7	(4%)
35 Food Preparation and Serving Related	39	(13%)	5	(3%)
37 Building and Grounds Cleaning and Maintenance	63	(21%)	40	(21%)
39 Personal Care and Service	19	(6%)	4	(2%)
41 Sales and Related	6	(2%)	11	(6%)
43 Office and Administrative Support	17	(6%)	10	(5%)
45 Farming, Fishing, and Forestry	8	(3%)	4	(2%)
47 Construction and Extraction	6	(2%)	6	(3%)
49 Installation, Maintenance, and Repair	20	(7%)	7	(4%)
51 Production	29	(10%)	14	(7%)
53 Transportation and Material Moving	15	(5%)	34	(18%)
99 Unknown or Non-classifiable	21	(7%)	17	(9%)
Industry, NAICS, n (%)				
Other (22, 23, 42, 52, 53, 54, 71)[h]	34	(12%)	22	(12%)
11 Agriculture, Forestry, Fishing and Hunting	13	(4%)	9	(5%)
31/32/33 Manufacturing	37	(13%)	13	(7%)
44/45 Retail Trade	18	(6%)	25	(13%)
48/49 Transportation and Warehousing	5	(2%)	18	(9%)
56 Administrative and Support and Waste Management and Remediation Services	26	(9%)	17	(9%)
61 Educational Services	19	(6%)	21	(11%)
62 Health Care and Social Assistance	70	(24%)	34	(18%)
72 Accommodation and Food Services	40	(14%)	17	(9%)
81 Other Services (except Public Administration)	15	(5%)	7	(4%)
92 Public Administration	18	(6%)	8	(4%)

[a] FTE, full-time equivalent; proportion evaluated using FTE totals for each of pre-pandemic and pandemic era.

[b] WC, workers' compensation; proportion evaluated using WC totals for each of pre-pandemic and pandemic era.

[d] Percent of the total number of all cleaning and disinfectant exposures for each of pre-pandemic and pandemic era. Since claims may have up to six AOEC exposure codes assigned (workers can be exposed to many hazards simultaneously - most have 1, very few have 3 or more), the arithmetic sum of all exposures may exceed the actual number of claims.

[e] Time-loss days are received when a worker cannot work for >3 days following the date of injury.

[f] IQR, interquartile range; the median claim cost was calculated from claims in which monetary compensation was paid to the worker - claims in which there was no monetary compensation were omitted.

[g] Standard Occupation Classification codes: 13 (Business and Financial Operations Occupations), 15 (Computer and Mathematical Occupations), 17 (Architecture and Engineering Occupations), 19 (Life, Physical, and Social Science Occupations), 21 (Community and Social Service Occupations), 23 (Legal Occupations), 25 (Educational Instruction and Library Occupations), 27 (Arts, Design, Entertainment, Sports, and Media Occupations), and 33 (Protective Service Occupations).

[h] North American Industry Classification Coding System codes: 22 (Utilities), 23 (Construction), 42 (Wholesale Trade), 52 (Finance and Insurance), 53 (Real Estate Rental and Leasing), 54 Professional, Scientific, and Technical Services), and 71 (Arts, Entertainment, and Recreation).

Table 2. Washington State workers' compensation claims from toxic inhalation injuries or work-related asthma due to cleaning and disinfecting substances, 2019 and 2020 by quarter.

	2019				2020			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Descriptive statistics								
Total, n	22	35	25	15	39	19	17	16
Total/FTE[a], per 100,000 FTE	3.900	5.668	4.050	2.468	6.846	3.780	2.945	2.771
Total/general WC claims[b], per 10,000 claims	6.126	9.162	5.96	3.927	11.27	6.556	5.116	4.86
Total/TI WC claims (TI surveillance data only)[c]	0.122	0.159	0.108	0.075	0.192	0.205	0.1	0.183
Sex								
Male, n	10	11	13	6	15	8	5	6
%	45	31	52	40	38	42	29	38
Age								
Mean per quarter, M	40	41	36	43	43	43	41	43
SD	16	14	16	15	16	12	16	16
Insurance type								
State fund, n	20	33	22	14	35	14	17	13
%	91	94	88	93	90	74	100	81
Exposure (AOEC exposure code), n[d]								
All disinfectants and cleaning materials (050.280, 322.xxx)	35	49	30	21	47	26	23	22
Disinfectants (050.280 and 322.190)	6	6	2	2	21	10	10	9
Cleaning materials (322.xxx, excluding 322.190)	29	43	28	19	26	16	13	13
Ammonia (322.070/090)		5	1		1			
Bleach (322.100/110/120/130)	7	5	13	7	11	5	5	1
Quaternary ammonium compounds (322.32x)	4	3	1		3	3	1	5
Severity, n								
Fatality								
Hospitalization								
Disability award	1			1	1	1		
Compensability status								
Compensable	2	3	2	1	5	4		6
Non-compensable	10	24	11	11	17	6	11	5
Rejected	9	8	11	3	16	9	6	5
Pending	1		1		1			
Claims with >= 1 time-loss day, n (% of claims)[e]	2	1	1	1	3	2	0	3

Claim cost $, Mdn[f]	373	446	578	262	486	648	961	897
Occupation, SOC, n								
Other (13, 15, 17, 19, 21, 23, 25, 27, 33)[g]	2	2	0	3	1	3	3	2
11 Management	0	0	1	0	5	0	1	0
29 Healthcare Practitioners and Technical	1	3	3	0	3	1	0	1
31 Healthcare Support	0	3	0	1	2	0	1	1
35 Food Preparation and Serving Related	3	1	2	3	0	0	1	0
37 Building and Grounds Cleaning and Maintenance	3	6	7	2	6	2	4	4
39 Personal Care and Service	1	4	2	1	0	0	1	0
41 Sales and Related	1	0	0	0	1	2	2	1
43 Office and Administrative Support	0	6	2	0	2	3	1	0
45 Farming, Fishing, and Forestry	2	2	1	0	0	0	0	1
47 Construction and Extraction	2	0	0	0	1	0	0	0
49 Installation, Maintenance, and Repair	3	1	3	2	1	1	0	0
51 Production	3	6	2	1	5	0	1	0
53 Transportation and Material Moving	0	1	0	1	10	3	2	6
99 Unknown or Non-classifiable	1	0	2	1	2	4	0	0
Industry, NAICS, n								
Other (22, 23, 42, 52, 53, 54, 71)[h]	6	5	1	1	5	1	3	1
11 Agriculture, Forestry, Fishing and Hunting	2	1	2	0	2	0	1	1
31/32/33 Manufacturing	3	6	5	2	2	2	0	1
44/45 Retail Trade	3	0	1	1	6	5	3	2
48/49 Transportation and Warehousing	0	0	2	0	7	1	1	3
56 Administrative and Support and Waste Management and Remediation Services	3	2	2	1	1	0	3	1
61 Educational Services	0	3	1	1	7	2	2	3
62 Health Care and Social Assistance	1	8	5	4	6	4	2	3
72 Accommodation and Food Services	3	2	2	1	1	1	1	0
81 Other Services (except Public Administration)	0	3	1	1	0	0	0	0
92 Public Administration	1	5	3	3	2	3	1	1

[a] FTE, full-time equivalent; proportion evaluated using FTE totals for each of pre-pandemic and pandemic era.
[b] WC, workers' compensation; proportion evaluated using WC totals for each of pre-pandemic and pandemic era.
[c] Proportion evaluated using data from toxic inhalation surveillance data set only, excluding the occupational respiratory disease surveillance data set.
[d] Since claims may have up to six AOEC exposure codes assigned (workers can be exposed to many hazards simultaneously - most have 1, very few have 3 or more), the arithmetic sum of all exposures may exceed the actual number of claims.
[e] Time-loss days are received when a worker cannot work for >3 days following the date of injury.
[f] IQR, interquartile range; the median claim cost was calculated from claims in which monetary compensation was paid to the worker - claims in which there was no monetary compensation were omitted.
[g] Standard Occupation Classification codes: 13 (Business and Financial Operations Occupations), 15 (Computer and Mathematical Occupations), 17 (Architecture and Engineering Occupations), 19 (Life, Physical, and Social Science Occupations), 21 (Community and Social Service Occupations), 23 (Legal Occupations), 25 (Educational Instruction and Library Occupations), 27 (Arts, Design, Entertainment, Sports, and Media Occupations), and 33 (Protective Service Occupations).
[h] North American Industry Classification Coding System codes: 22 (Utilities), 23 (Construction), 42 (Wholesale Trade), 52 (Finance and Insurance), 53 (Real Estate Rental and Leasing), 54 Professional, Scientific, and Technical Services), and 71 (Arts, Entertainment, and Recreation).

Table 3. Incidence rate and incidence risk ratios for association between pre-pandemic and pandemic era, 1 Jan 2017 - 30 Jun 2022.

	Pre-pandemic era (1 Jan 2017 – 31 Dec 2019)	**Pandemic era (1 Jan 2020 – 30 Jun 2022)**	**Incidence ratio (95% CI)**	**2019 Q1 1 Jan - 31 Mar**	**2020 Q1 1 Jan - 31 Mar**	**Incidence ratio (95% CI)**
Claims, TI and ORD surveillance data sets						
Total, n	295	191		22	39	
Total/FTE[a], per 100,000 FTE	4.18	3.32	**0.79 (0.66, 0.95)**[b]	3.90	6.85	**1.76 (1.04, 2.96)**[b]
Total/general WC claims[c], per 10,000 claims	6.38	5.69	0.89 (0.74, 1.07)[d]	6.13	11.27	**1.84 (1.09, 3.10)**[d]
Claims, TI surveillance data set						
Total, n	289	178		22	34	
Total/TI WC claims (TI surveillance data only)[e]	0.13	0.16	**1.27 (1.07, 1.50)**[d]	0.12	0.19	1.58 (0.96, 2.59)[d]

[a] FTE, full-time equivalent; proportion evaluated using FTE totals for each of pre-pandemic and pandemic era.

[b] Two-sample inference for incidence-rate, p = 0.05.

[c] WC, workers' compensation; proportion evaluated using WC totals for each of pre-pandemic and pandemic era.

[d] Chi-squared test of differences in proportions, p = 0.05.

[e] Proportion evaluated using data from toxic inhalation surveillance data set only, excluding the occupational respiratory disease surveillance data set.

Table 4. Washington State workers' compensation claims from toxic inhalation injuries or work-related asthma due to cleaning and disinfecting substances, 2017 - 2022 by quarter.

	2017				**2018**				**2019**				**2020**				**2021**				**2022**	
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Descriptive statistics																						
Total, n	27	23	29	13	25	34	24	23	22	35	25	15	39	19	17	16	28	19	13	18	15	7
Total/FTE[a], per 100,000 FTE	5.0	4.0	5.0	2.3	4.5	5.6	3.9	3.8	3.9	5.7	4.1	2.5	6.8	3.8	2.9	2.8	5.2	3.2	2.2	3.0	2.7	1.1
Total/general WC claims[b], per 10,000 claims	7.2 61	6.0 01	7.3 25	3.4 76	6.8 07	8.5 18	5.8 62	6.0 01	6.1 26	9.1 62	5.9 6	3.9 27	11. 27	6.5 56	5.1 16	4.8 6	9.1 61	5.6 85	3.6 25	5.2 54	4.0 84	1.9 89
Total/TI WC claims (TI surveillance data only)[c]	0.1 54	0.1 06	0.1 49	0.0 79	0.1 7	0.1 42	0.1 31	0.1 41	0.1 22	0.1 59	0.1 08	0.0 75	0.1 92	0.2 05	0.1	0.1 83	0.2 83	0.2 25	0.1 05	0.1 73	0.1 46	0.0 71
Sex																						
Male, n	12	7	16	3	12	15	13	13	10	11	13	6	15	8	5	6	10	5	10	8	6	3
%	44	30	55	23	48	44	54	57	45	31	52	40	38	42	29	38	36	26	77	44	40	43
Age																						
Mean per quarter, M	40	41	36	43	43	43	41	43	40	41	36	43	43	43	41	43	40	41	36	43	43	43
SD	16	14	16	15	16	12	16	16	16	14	16	15	16	12	16	16	16	14	16	15	16	12
Insurance type																						
State fund, n	25	21	28	11	23	32	22	23	20	33	22	14	35	14	17	13	23	19	13	18	14	5
%	93	91	97	85	92	94	92	100	91	94	88	93	90	74	100	81	82	100	100	100	93	71
Exposure (AOEC exposure code), n[d]																						
All disinfectants and cleaning materials (050.280, 322.xxx)	33	29	46	15	39	54	36	40	35	49	30	21	47	26	23	22	42	33	18	28	21	7
Disinfectants (050.280 and 322.190)	3	3	4	2	2	3	2	2	6	6	2	2	21	10	10	9	10	2	2	3	1	1
Cleaning materials (322.xxx, excluding 322.190)	30	26	42	13	37	51	34	38	29	43	28	19	26	16	13	13	32	31	16	25	20	6
Ammonia (322.070/090)		1	1		1					5	1		1							1	1	

Bleach (322.100/110/120/130)	10	9	24	5	9	15	10	12	7	5	13	7	11	5	5	1	9	12	5	8	4	
Quaternary ammonium compounds (322.32x)		1			1			1	4	3	1		3	3	1	5	13	2	1	6	1	
Severity, n																						
Fatality					0														1			
Hospitalization						1		1									1					
Disability						1			1			1	1	1			2					
Compensability status																						
Compensable	3		1		1	2			2	3	2	1	5	4		6	2	2		3	2	1
Non-compensable	16	14	22	8	18	24	16	12	10	24	11	11	17	6	11	5	13	10	7	4	10	3
Rejected	7	8	5	4	6	8	7	10	9	8	11	3	16	9	6	5	13	6	4	9	2	1
Pending	1	1	1	1			1	1	1		1		1					1	2	2	1	2
Claims with >= 1 time-loss day, n (% of claims)[e]	2	0	1	1	1	2	0	0	2	1	1	1	3	2	0	3	1	2	0	3	1	0
Claim cost $, Mdn[f]	91	55	43	34	83	85	72	44	37	44	57	26	48	64	96	89	58	82	45	61	57	32
	8	7	0	57	0	2	1	9	3	6	8	2	6	8	1	7	5	1	6	3	4	12
Occupation, SOC, n																						
Other (13, 15, 17, 19, 21, 23, 25, 27, 33)[g]	1	1	1	0	1	3	0	0	2	2	0	3	1	3	3	2	1	1	0	3	1	0
11 Management	1	0	2	0	1	0	0	0	0	0	1	0	5	0	1	0	1	0	0	0	1	0
29 Healthcare Practitioners and Technical	2	2	3	0	1	1	2	3	1	3	3	0	3	1	0	1	2	0	1	0	1	0
31 Healthcare Support	3	3	0	0	1	0	1	0	0	3	0	1	2	0	1	1	2	0	0	1	0	0
35 Food Preparation and Serving Related	5	0	3	2	2	7	6	5	3	1	2	3	0	0	1	0	1	0	2	1	0	0
37 Building and Grounds Cleaning and Maintenance	5	6	7	6	4	7	5	5	3	6	7	2	6	2	4	4	6	6	5	2	5	0
39 Personal Care and Service	0	1	2	0	2	4	1	1	1	4	2	1	0	0	1	0	0	2	0	1	0	0
41 Sales and Related	1	2	1	0	0	0	0	1	1	0	0	0	1	2	2	1	2	0	0	2	1	0
43 Office and Administrative Support	0	1	1	0	3	2	0	2	0	6	2	0	2	3	1	0	0	2	1	1	0	0

45 Farming, Fishing, and Forestry	0	0	0	0	0	2	1	0	2	2	1	0	0	0	0	1	2	0	1	0	0	0
47 Construction and Extraction	0	3	0	0	0	1	0	0	2	0	0	0	1	0	0	0	0	0	0	3	1	1
49 Installation, Maintenance, and Repair	1	1	4	0	3	1	1	0	3	1	3	2	1	1	0	0	1	1	0	1	1	1
51 Production	4	0	3	2	2	3	1	2	3	6	2	1	5	0	1	0	0	5	2	1	0	0
53 Transportation and Material Moving	3	1	1	1	1	1	1	4	0	1	0	1	10	3	2	6	5	2	1	1	3	1
99 Unknown or Non-classifiable Industry, NAICS, n	1	2	1	2	4	2	5	0	1	0	2	1	2	4	0	0	5	0	0	1	1	4
Other (22, 23, 42, 52, 53, 54, 71)[h]	3	2	8	1	0	3	1	3	6	5	1	1	5	1	3	1	4	2	0	5	1	0
11 Agriculture, Forestry, Fishing and Hunting	0	1	0	0	0	3	3	1	2	1	2	0	2	0	1	1	4	0	1	0	0	0
31/32/33 Manufacturing	9	1	2	1	3	2	1	2	3	6	5	2	2	2	0	1	2	2	2	1	0	1
44/45 Retail Trade	2	2	0	0	2	2	2	3	3	0	1	1	6	5	3	2	1	1	3	2	1	1
48/49 Transportation and Warehousing	1	0	1	0	0	0	0	1	0	0	2	0	7	1	1	3	4	1	0	1	0	0
56 Administrative and Support and Waste Management and Remediation Services	0	3	0	3	2	5	3	2	3	2	2	1	1	0	3	1	2	2	1	2	4	1
61 Educational Services	1	2	4	1	1	1	3	1	0	3	1	1	7	2	2	3	1	2	1	3	0	0
62 Health Care and Social Assistance	8	8	6	3	8	9	4	6	1	8	5	4	6	4	2	3	5	4	2	3	4	1
72 Accommodation and Food Services	3	1	4	2	6	7	6	3	3	2	2	1	1	1	1	0	2	4	3	0	3	2
81 Other Services (except Public Administration)	0	2	2	2	2	0	1	1	0	3	1	1	0	0	0	0	3	1	0	0	2	1
92 Public Administration	0	1	2	0	1	2	0	0	1	5	3	3	2	3	1	1	0	0	0	1	0	0

[a] FTE, full-time equivalent; proportion evaluated using FTE totals for each of pre-pandemic and pandemic era.

[b] WC, workers' compensation; proportion evaluated using WC totals for each of pre-pandemic and pandemic era.

[c] Proportion evaluated using data from toxic inhalation surveillance data set only, excluding the occupational respiratory disease surveillance data set.

[d] Since claims may have up to six AOEC exposure codes assigned (workers can be exposed to many hazards simultaneously - most have 1, very few have 3 or more), the arithmetic sum of all exposures may exceed the actual number of claims.

[e] Time-loss days are received when a worker cannot work for >3 days following the date of injury.

[f] IQR, interquartile range; the median claim cost was calculated from claims in which monetary compensation was paid to the worker - claims in which there was no monetary compensation were omitted.

[g] Standard Occupation Classification codes: 13 (Business and Financial Operations Occupations), 15 (Computer and Mathematical Occupations), 17 (Architecture and Engineering Occupations), 19 (Life, Physical, and Social Science Occupations), 21 (Community and Social Service Occupations), 23 (Legal Occupations), 25 (Educational Instruction and Library Occupations), 27 (Arts, Design, Entertainment, Sports, and Media Occupations), and 33 (Protective Service Occupations).

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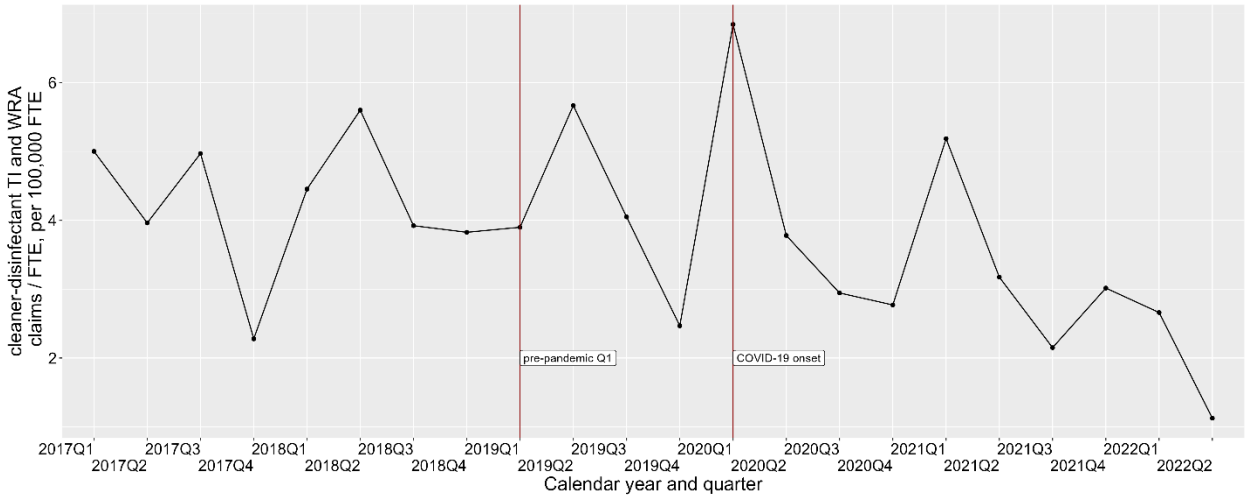

Figure 1. Toxic inhalation and work-related asthma claims from cleaner-disinfectant exposures, as a proportion of the total number of full-time employed workers in Washington State, 2017 – 2022.

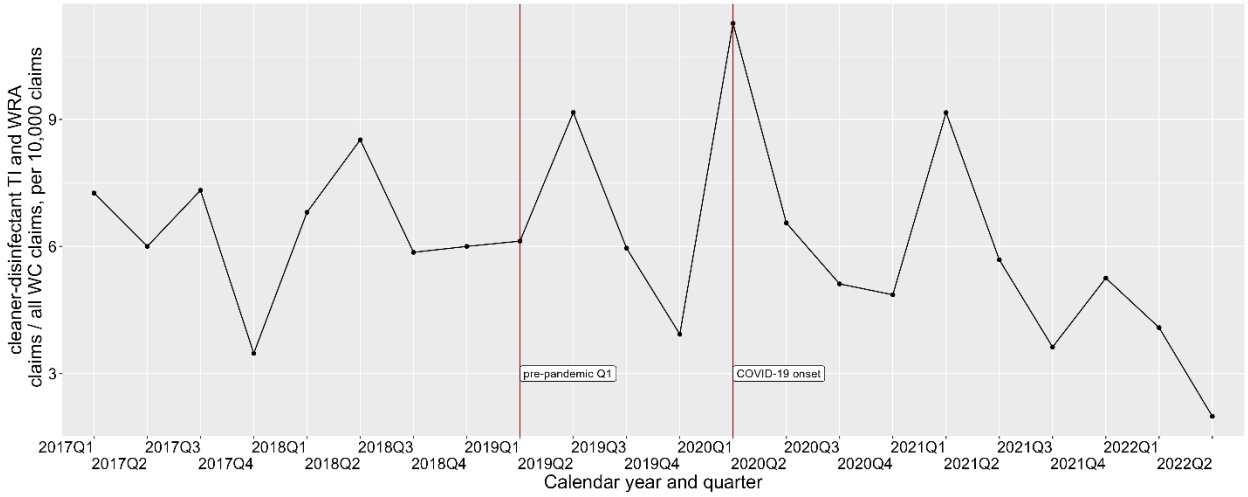

Figure 2. Toxic inhalation and work-related asthma claims from cleaner-disinfectant exposures, as a proportion of all workers' compensation claims in Washington State, 2017 – 2022.

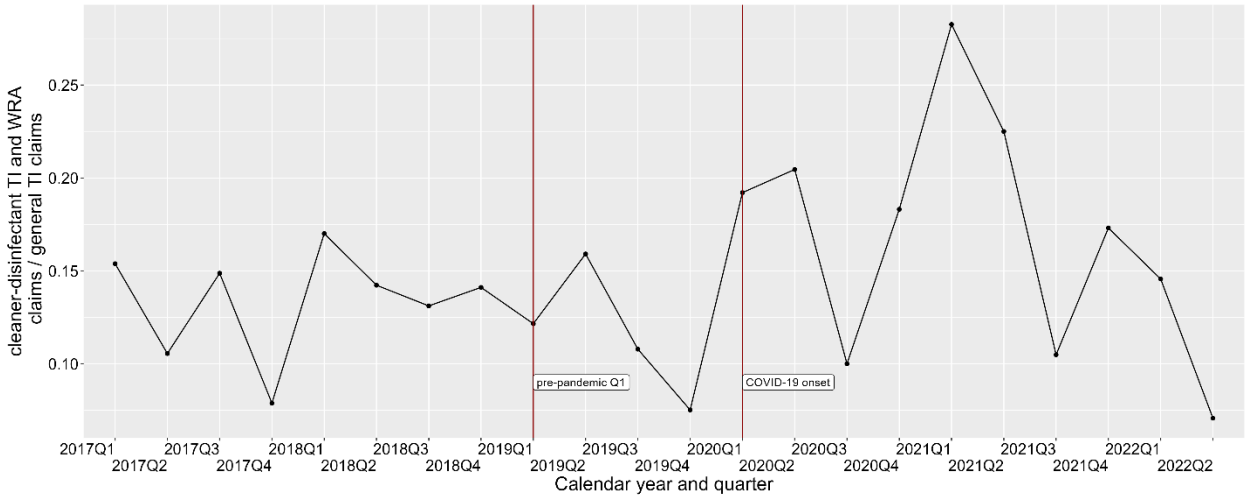

Figure 3. Toxic inhalation and work-related asthma claims from cleaner-disinfectant exposures, as a proportion of all claims from the toxic inhalation surveillance data set in Washington State, 2017 – 2022.

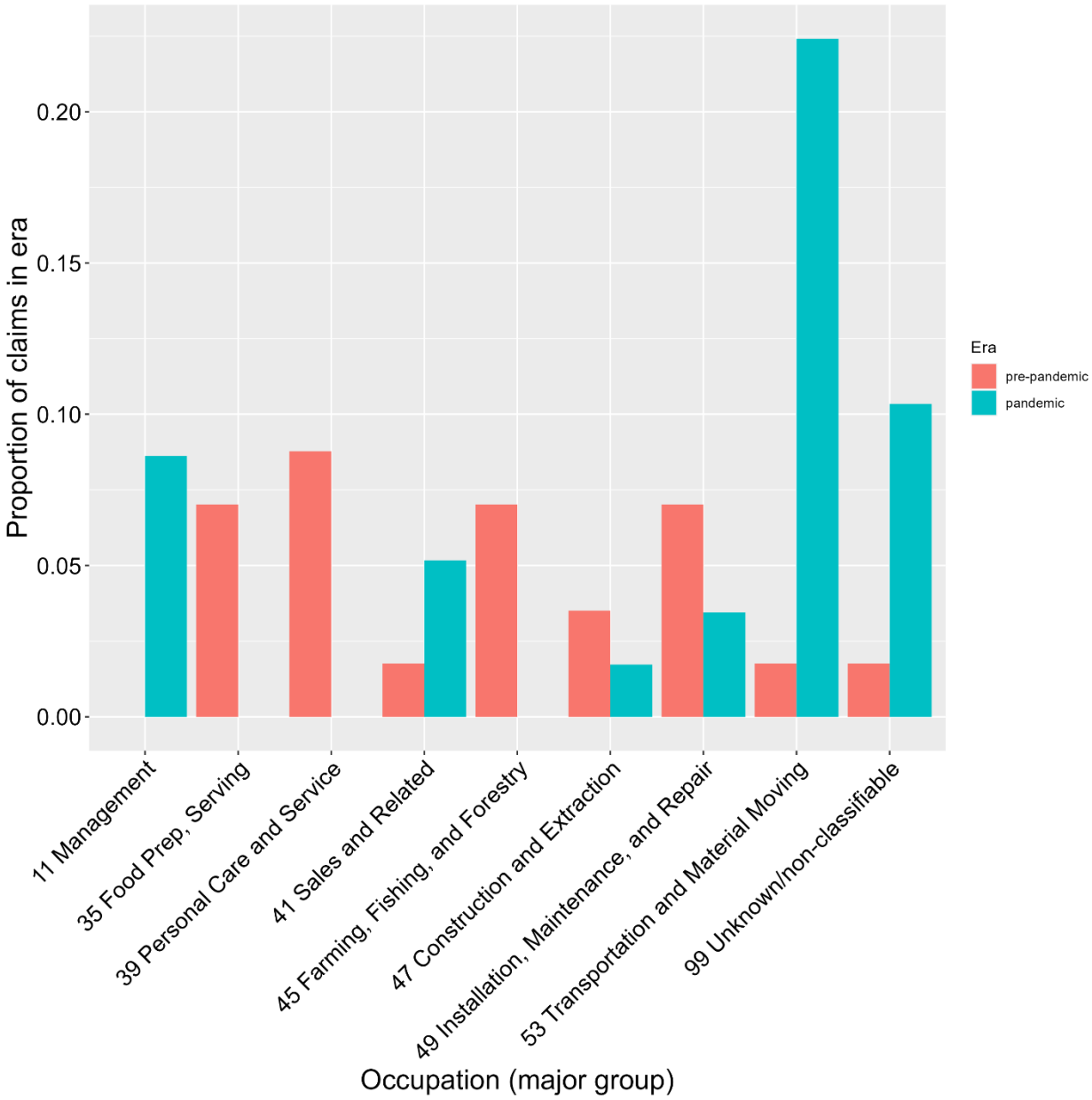

Figure 4. Proportion of claims filed by occupations in each era where red represents proportions from the pre-pandemic era (2017 Q1 – 2019 Q4) and green represents proportions from the pandemic era (2020 Q1 – 2022 Q2). Only occupations in which there was a >=50% change in their proportional representation between the two eras are plotted.

"00 Other" category comprises 13 (Business and Financial Operations Occupations), 15 (Computer and Mathematical Occupations), 17 (Architecture and Engineering Occupations), 19 (Life, Physical, and Social Science Occupations), 21 (Community and Social Service Occupations), 23 (Legal Occupations), 25 (Educational Instruction and Library Occupations), 27 (Arts, Design, Entertainment, Sports, and Media Occupations), and 33 (Protective Service Occupations).

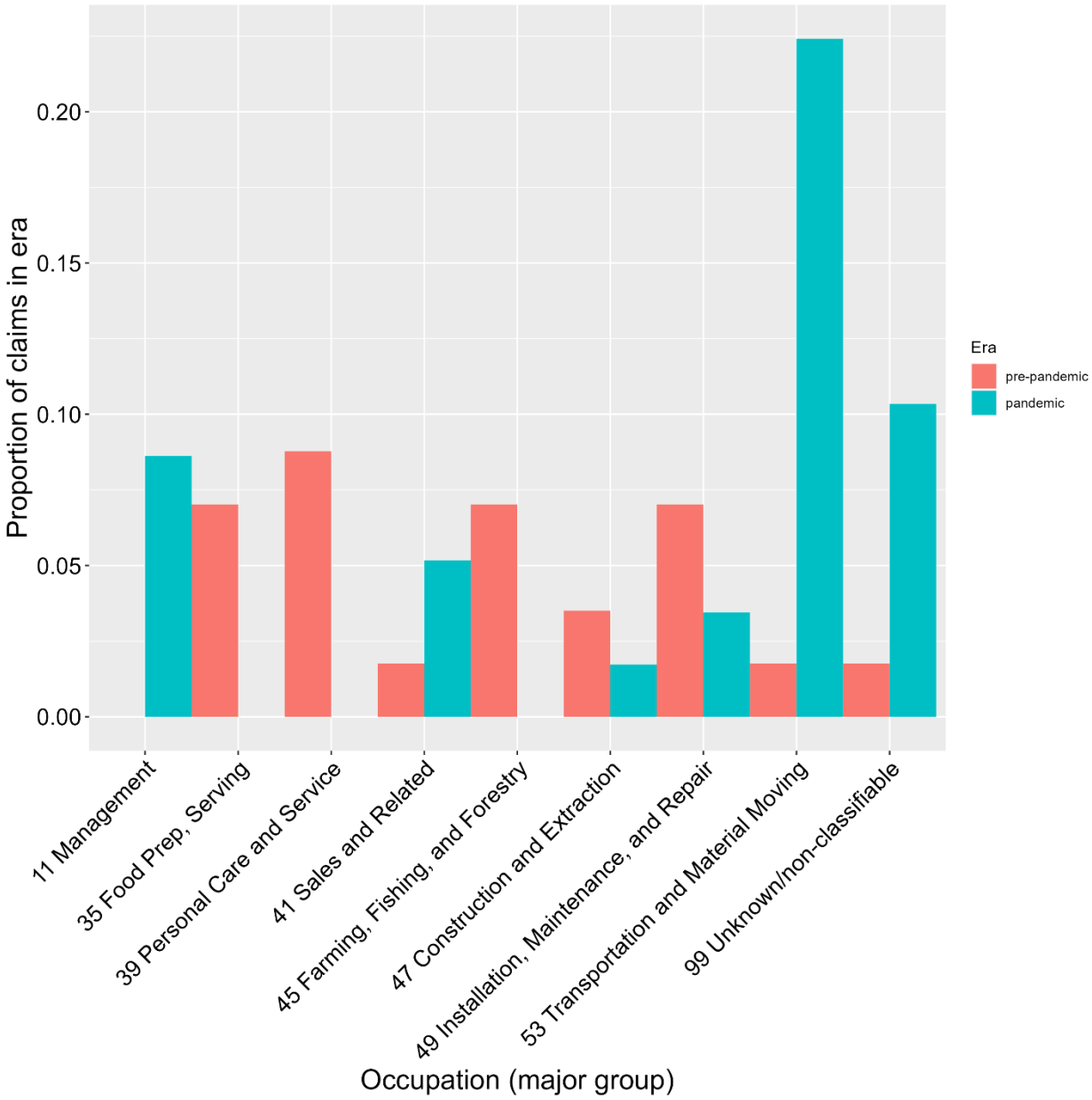

Figure 5. Proportion of claims filed by occupations in each era where red represents proportions from first two quarters of 2019 (pre-pandemic era) and green represents proportions from the first two quarters of 2020 (pandemic era). Only occupations in which there was a >=50% change in their proportional representation between the two eras are plotted.

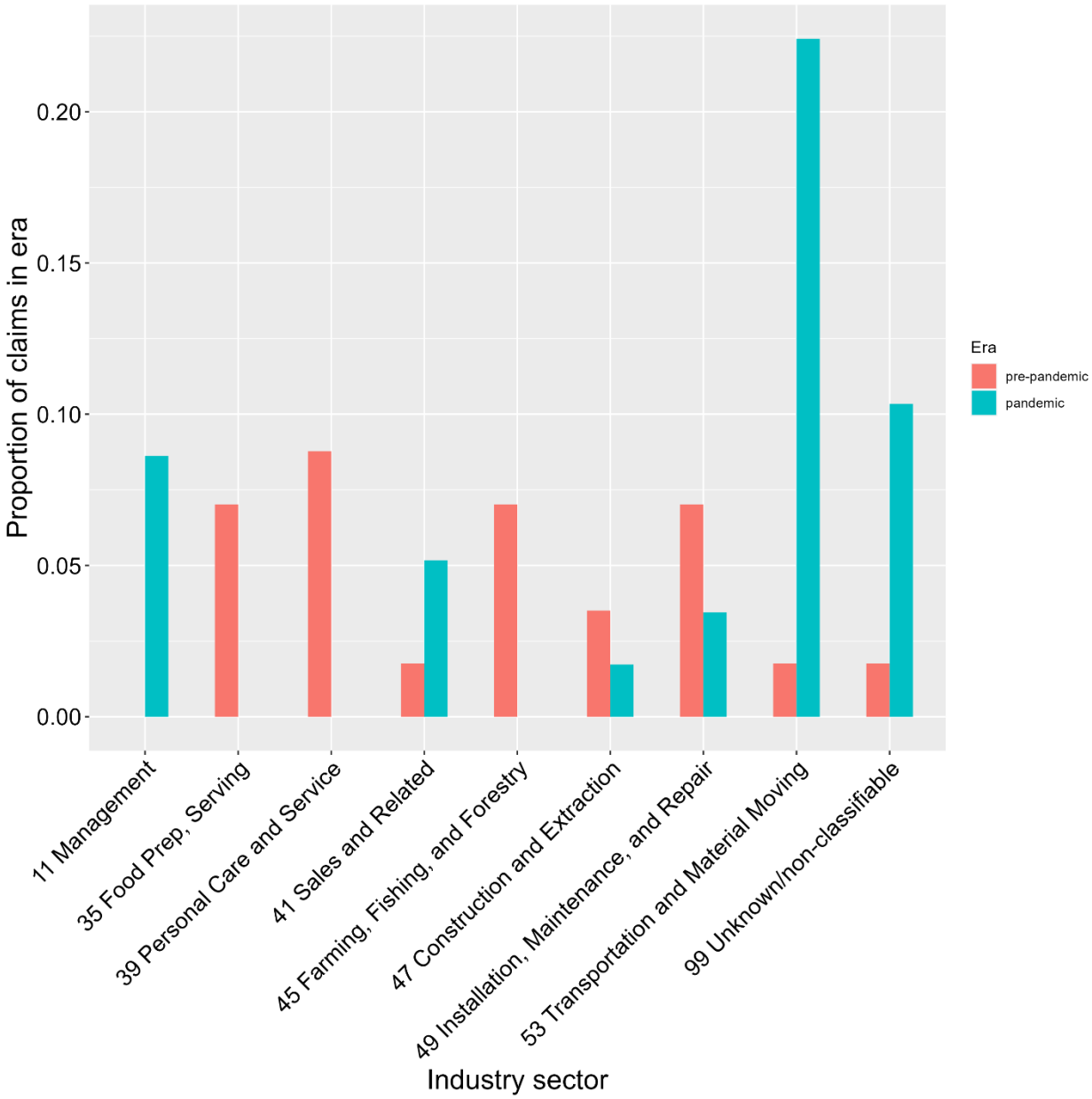

Figure 6. Proportion of claims filed by industry sectors in each era where red represents proportions from the pre-pandemic era (2017 Q1 – 2019 Q4) and green represents proportions from the pandemic era (2020 Q1 – 2022 Q2). Only industry sectors in which there was a >=50% change in their proportional representation between the two eras are plotted.

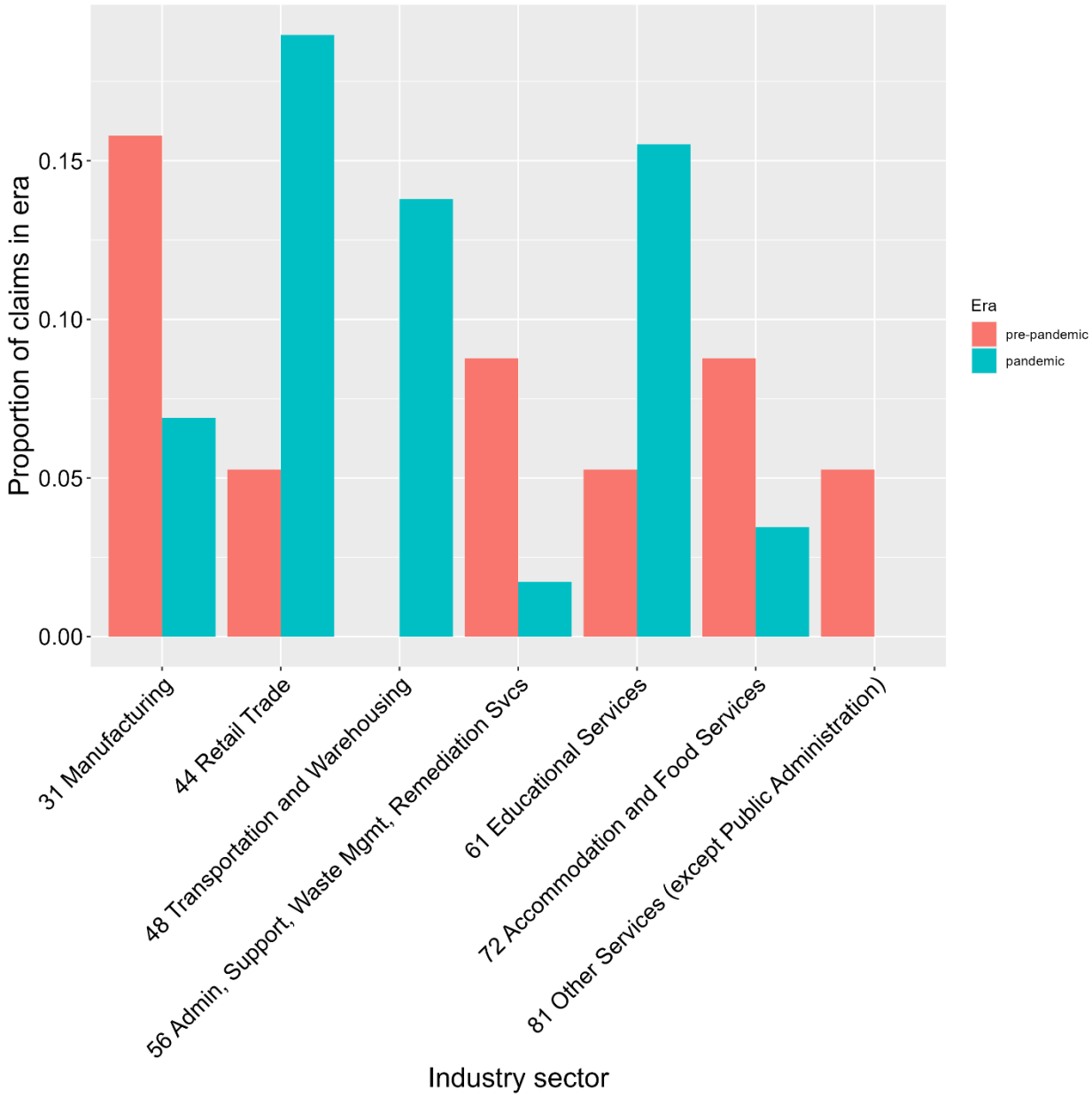

Figure 7. Proportion of claims filed by industry sectors in each era where red represents proportions from first two quarters of 2019 (pre-pandemic era) and green represents proportions from the first two quarters of 2020 (pandemic era). Only industry sectors in which there was a >=50% change in their proportional representation between the two eras are plotted.

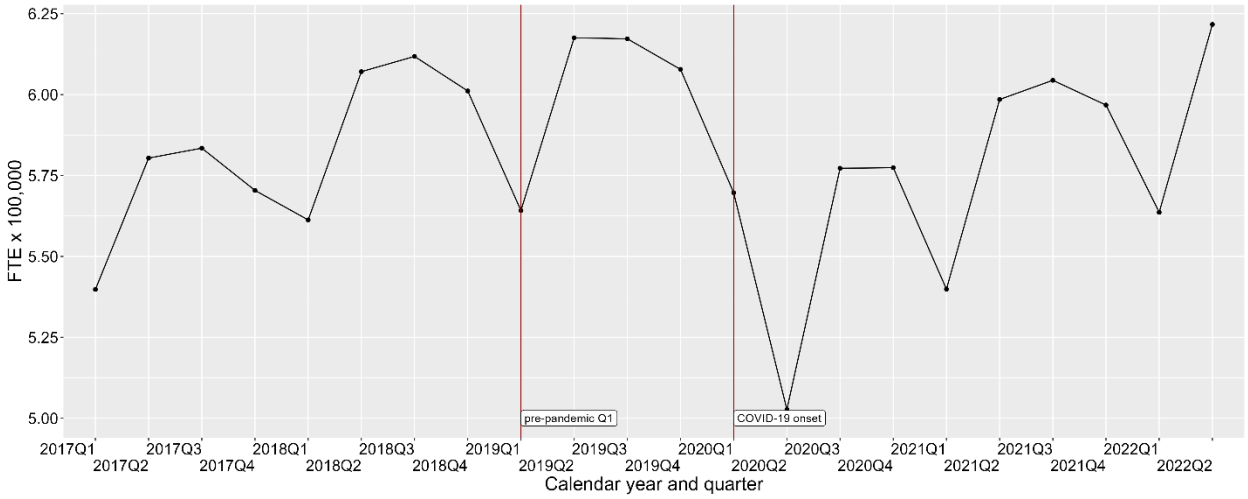

Figure 8. Full-time equivalent (FTE) employee quarterly trend in Washington State, 2017 – 2022.

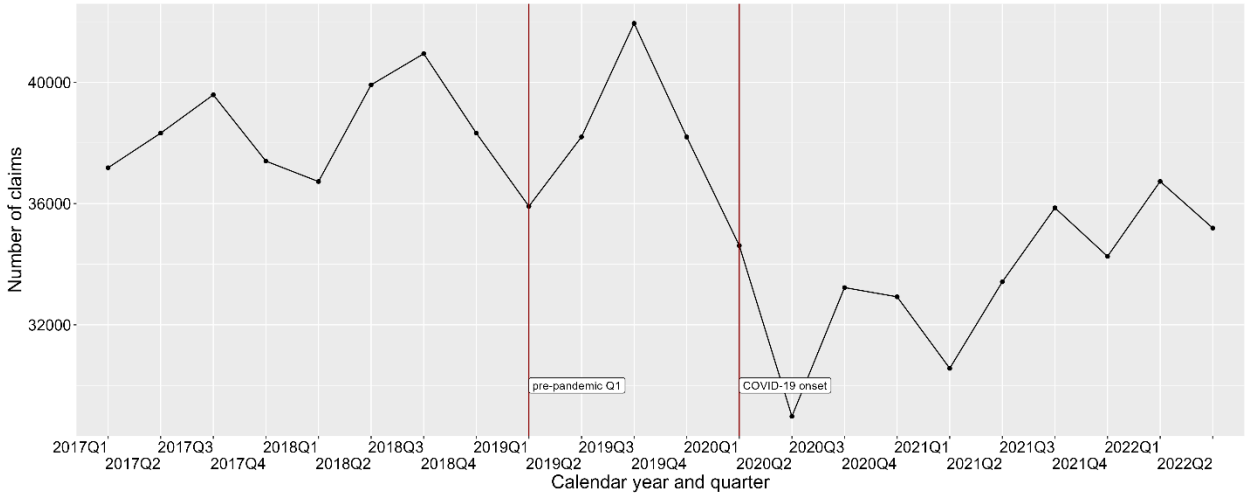

Figure 9. WC claims quarterly trend in Washington State, 2017 – 2022.

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