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Sun Exposure in Outdoor Workers: Measurements and Monitoring

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Executive Summary

Outdoor workers are exposed to numerous workplace hazards. These hazards or exposures place them at risk for a wide variety of negative health outcomes, including cancers, heat stress and hypothermia, respiratory diseases, skin problems, infections, and physical injuries (for example from falls, equipment, or animals). In particular, solar ultraviolet radiation (UVR) is a substantial risk factor for outdoor workers and has been underestimated and often neglected as an occupational risk [1]. In this study our objectives were to assess:

1. What are the typical full-day UVR exposure levels for outdoor workers in Alberta?
2. What are the best practices for creating a sun exposure and skin cancer surveillance system for outdoor workers in Alberta?

This report presents the results of our program of research on outdoor workers health as it relates to their exposure to solar UVR. Our study involved two distinct sub-projects, one that was largely quantitative in nature (exposure assessment for solar UVR in outdoor workers), and one that was largely qualitative (assessing the best way to design a surveillance program for the occupational health of outdoor workers).

UVR measurement sub-study:

The purpose of the first sub-study was to collect personal solar UVR exposure measurements from workers in Alberta and to assess which personal, work, and environmental factors are important determinants of personal daily solar UVR exposure. Key outcomes of this sub-study included:

- This study collected objective solar UVR measurements from outdoor workers primarily in Alberta during the summer of 2019.
- In total, 883 measurements were collected from 179 workers using personal UVR dosimeters.
- On average, workers were exposed to 1.93 Standard Erythemal Dose (SED) (range: 0.03-16.63 SED) per day.
- Almost half of the workers were exposed to levels that exceeded the international occupational exposure limit guideline (1.3 SED).

Monitoring sub-study:

The purpose of the second sub-study was to investigate via a literature review and key informant interviews whether occupational surveillance has been conducted for outdoor workers previously, to identify the key planning components for structuring an effective occupational surveillance program and to better understand the best practices for the design and implementation of a potential surveillance system for outdoor workers. Key findings and outcomes of this sub-study included:

- No countries have designed or implemented an occupational surveillance system focused solely on outdoor workers.
- Numerous surveillance strategies exist and 5 of these strategies were investigated in depth.
- Underreporting/under-participation is a key barrier while communication/collaboration is a key facilitator in the design and implementation of an occupational surveillance program.
- 10 key considerations in the design of an occupational surveillance program were identified.
- 5 recommendations for an occupational surveillance system focused on non-melanoma skin cancer (NMSC) are proposed.

Overall conclusions:

Our study demonstrated that sun exposure is a clear occupational hazard for outdoor workers in Alberta, and that there are few examples worldwide of jurisdictions who have surveillance systems in place to support the exposure and NMSC risk reduction in this vulnerable worker population. Programs have been developed in Canada over the years to help support employers in controlling exposure to solar UVR among their workers, but evaluation of these programs has been limited to date. This speaks very much to our finding from this study that sustained funding, data infrastructure, and clear communication and collaboration are vital to the tackling of occupational skin cancer prevention as well as the undertaking of occupational hazard and health surveillance more broadly.

Recommendations for future research:

We have identified some areas for future research and propose the following:

- Additional UVR sampling campaigns should be undertaken in subsequent summers in Alberta as well as in different regions in Canada.
- Systems should be designed and created to better track the incidence of NMSC in Alberta and elsewhere in Canada.
- Future research should address the issue of other occupational health hazards experienced by outdoor workers, including solar UVR exposure, but expanding into other co-exposures experienced by this group.

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Section 1: Figures, tables, acronyms

1.1 List of figures

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1.3 List of acronyms

AK	Actinic Keratosis
AHS	Alberta Health Services
BC	British Columbia
BCC	Basal Cell Carcinoma
CDC	Centers for Disease Control and Prevention
COEH	Centre for Occupational and Environmental Health (Manchester)
CWHSP	Coal Workers' Health Surveillance Program
DGUV	Deutsche Gesetzliche Unfallsversicherung (German Social Accident Insurance)
ECWHSP	Enhanced Coal Workers Health Surveillance Program
HSE	Health and Safety Executive
IARC	International Agency for Research on Cancer
MSHA	Mine Safety and Health Administration
NIOSH	National Institute for Occupational Safety and Health
NLI	Norwegian Labour Inspectorate
NMSC	Non-Melanoma Skin Cancer
OD	Occupational Disease
ODSS	Occupational Disease Surveillance System
OEL	Occupational Exposure Limit
OSD	Occupational Skin Disease
OHS	Occupational Health and Safety
EU-OSHA	European Agency for Safety and Health at Work
RAS	Norwegian Labor Inspectorate Registry for Work-Related disease
SCC	Squamous Cell Carcinoma
SED	Standard Erythemal Dose
THOR	The Health and Occupation Reporting network

UK	United Kingdom
UVI	Ultraviolet Index
UVR	Ultraviolet Radiation
WCB-Alberta	Workers’ Compensation Board-Alberta
WRD	Work Related Disease
WRSD	Work Related Skin Disease
WHO	World Health Organization
WorkSafeBC	Workers' Compensation Board of British Columbia
WSIB	Workplace Safety and Insurance Board (Ontario)

Section 2: Introduction

This report serves as a complete summary of our program of research on outdoor workers health as it relates to their exposure to solar ultraviolet radiation (UVR). Our study involved two distinct sub-projects, one that was largely quantitative in nature (exposure assessment for solar UVR in outdoor workers), and one that was largely qualitative (assessing the best way to design a surveillance program for the occupational health of outdoor workers).

The report is organized into the following sections:

Section 1 lists the figures/tables/acronyms that appear in the report

Section 2 introduces the report and describes how the information is organized.

Section 3 provides a general background on occupational exposure to solar UVR in Canada, including why it is of concern, the prevention of sun exposure, and the type and design of surveillance programs for outdoor workers. This section also includes the objectives that we sought to achieve in the course of this program of research.

Section 4 describes the first sub-project of our grant in detail, which involved the measurement of solar UVR exposure in a group of Alberta's outdoor workers. It is organized into three parts which include the methodology we used, the results of our field study, and a discussion and context of our results.

Section 5 reports on the second sub-project of our grant in detail, which involved a literature review and some in-depth key informant interviews to collect information on the surveillance of outdoor workers and their occupational health, specific to sun exposure (where possible). As well we outline the key considerations for designing an occupational surveillance system in Alberta and recommendations to help move towards a NMSC surveillance program.

Section 6 ties the whole program of research together and offers some conclusions and next steps. We provide some recommendations for where to go next in terms of understanding the extent and level of exposure to solar UVR in Alberta's outdoor workers, explain how the results are relevant to Alberta workers, workplaces, employers and decision makers and provide some additional recommendations for future research.

Section 3: Background & Literature Review

3.1 Sun exposure in outdoor workers

As of 2015, over 85,000 of the 275,000 newly diagnosed cancers in Canada were skin cancer, making it the most common cancer diagnosis in the country [2]. Although skin cancer is largely preventable (by limiting solar ultraviolet radiation (UVR) exposure), it is one of the only cancers for which incidence continues to increase in Canada and other western countries [3]. Outdoor workers are a group at high risk of prolonged and intense solar UVR exposure [4]. This pattern of exposure places them at increased risk of non-melanoma skin cancers (basal and squamous cell carcinomas), as well as actinic keratoses, which are pre-cancerous skin lesions.

Most previous research on occupational UVR exposure has been done in Australia and a few select European countries (Germany in particular), and data on measured values of UVR for Canadian workers is scarce; to date, no data is available from the province of Alberta. This is despite the fact that 1.5 million Canadians (and over 225,000 in Alberta) are exposed to solar UVR at work [5], and that Alberta has some of the highest ambient UVR in the country (due primarily to elevation and weather patterns). It has been estimated that over 4,500 new cases of non-melanoma skin cancer each year in Canada are attributable to occupational solar UVR exposure [6]. This represents a significant physical and mental cost to workers themselves, as well as an economic cost to the health care system. Solar UVR exposure also contributes to a number of other health outcomes. Although rarely fatal itself, a diagnosis of non-melanoma skin cancer increases the risk of a recurrent skin cancer, and also doubles the risk of some other non-cutaneous cancers [7]. Other health risks from solar UVR exposure include cataracts, ocular melanoma, solar (actinic) keratoses, skin aging, and negative immune system effects [8].

3.2 Prevention of occupational sun exposure

Reduction of the impact of occupational disease can occur on the continuum of primary, secondary, and tertiary prevention. Primary prevention (reducing a risk factor for disease prior to illness occurring) is the ideal opportunity, but secondary (early detection and treatment) and tertiary (minimizing morbidity after disease occurs) prevention can also play key roles in limiting the harm of occupational diseases [9]. The major aspect of outdoor work that is challenging from a primary prevention standpoint is that many of the exposures of concern are difficult to control using classic methods. The hierarchy of controls is a system whereby hazard reduction is accomplished using tasks in this order of importance: elimination of the hazard, substitution to a less hazardous alternative, engineering controls, administrative arrangements to reduce exposure, and personal protective equipment as a last resort [10]. For several of the hazards experienced by outdoor workers, the best controls in terms of effectiveness are simply not available. We cannot completely eliminate or substitute solar UVR exposure, silica, infectious agents, or injury altogether, so we are forced to use less effective methods to reduce the risk of occupational injury and disease in outdoor workers.

Calls have been made to focus more research on the primary prevention of skin cancer in Canada [11], but the lack of documentation of levels of occupational exposure to solar UVR inhibits our ability to evaluate the effectiveness of workplace interventions. Interventions to reduce UVR exposure tend to focus on individual behaviours. The following recommendations are typically used in UVR exposure-reduction interventions [12]: 1) sun avoidance, shade seeking; 2) protective clothing (hats, closely-woven fabrics); 3) sunscreen; and, more rarely, 4) skin cancer screening. These strategies have ranged from small, targeted interventions to national strategies with moderate results and, in many cases, a continued increase in skin cancer incidence [13]. In addition, people tend to use sun protection improperly (i.e. not applying enough sunscreen and not re-applying often enough, wearing hats without proper brims). However, Australia and Scandinavia (regions with long histories of investment in prevention activities) have seen declines in skin cancer mortality, showing that prevention strategies can work [14].

The Sun Safety at Work Canada project and its associated toolkit provides a framework for employers to develop their own personalized sun safety program for outdoor workers, and preliminary results suggest that these programs are easy to use and provide a useful and tailored approach to reducing the risk of sun exposure and heat stress in Canada's outdoor workers [15]. This project focuses on primary prevention, but other systems in countries outside of Canada (primarily Germany) have also seen success using complementary secondary and tertiary prevention plans. The German system allows the general population aged 35 and up to seek out skin screening once every two years as part of their health insurance plan [16]. Tertiary prevention for skin cancer includes following patients closely over time for recurrence (i.e. new cancers), as having one skin malignancy greatly increases the risk of having subsequent ones. In addition, these systems may also include skin screening for the immunosuppressed (such as people who have had an organ transplant), as they are at very high risk of epithelial cancers [16].

3.3 Surveillance as a tool to reduce occupational disease risk

According to a recent consensus report from the National Academies of Sciences, Engineering, and Medicine in the United States, the purpose of surveillance systems for occupational health and safety is to "provide(s) the data and analyses needed to understand the relationships between work and injuries and illnesses in order to improve worker safety and health and prevent work-related injuries and illnesses"[17]. Various methods for collecting and using data can be employed in an occupational health surveillance system, including exposure registries, occupational disease registries, disease screening/medical surveillance (such as for pneumoconiosis or signs of skin cancer), sentinel event surveillance, disease surveillance via data linkage, exposure surveillance and population-based surveys [18].

There are several examples of exposure registries in Canada that have been reviewed in detail in recent years [18, 19]. These can include monitoring of a specific group of workers from one locale (such as the Newfoundland Baie Verte Miners' Registry) up to population-based monitoring programs (such as the National Dose Registry for radiation exposed workers). They can focus on one exposure (such as radiation or asbestos) or be more open ended in terms of exposures of interest (such as the WorkSafeBC Exposure Registry Program). One of the main strengths of exposure registries is that workers are enrolled prior to the occurrence of disease, which allows for primary prevention work to take place.

Health or medical surveillance programs are also a useful tool in the prevention of occupational disease, especially for health problems that have early warning signs, or that have a better prognosis with early diagnosis and/or treatment (via secondary and tertiary prevention activities). Programs exist in various forms for hazards such as noise, vibration, asbestos, lead, solvents, radiation, and biological agents [20].

One key learning that resonates strongly in the available literature on occupational surveillance systems is the need for careful consideration and planning for any new surveillance-related program. It is important to consider setting clear goals of a surveillance system, to consult with key informants, to consider data needs and management plans, privacy and legal issues, and communication with relevant stakeholders [18].

A co-benefit of surveillance (secondary prevention) among outdoor workers is that the system could be leveraged to prevent multiple health outcomes beyond only skin cancer in the future. People who work outdoors experience a variety of challenging workplace situations that may place their health at risk, over and above the risks posed by solar UVR exposure. These include excessive heat or cold (extreme thermal environments)[21], exposure to infectious agents via insects (e.g. West Nile virus, Lyme disease) [22, 23], exposure to hazardous chemicals such as pesticides [24], exposure to photosensitizers that can increase the harm of solar UVR exposure (e.g. coal tar) [25], risk of injury (e.g. for outdoor construction workers [26]), exposure to organic [27] and inorganic [28] dusts, and exposure to hydrocarbons (such as via vehicle exhausts) [29]. These diverse workplace hazards place outdoor workers at risk of a wide variety of negative health outcomes, including but not limited to other cancers (beyond skin), heat stress and hypothermia, respiratory diseases, skin problems, infections, and physical injuries (for example from falls, equipment, or animals).

3.4 Research objectives:

The two main research objectives of this (primary prevention) project are:

1. What are the typical full-day UVR exposure levels for outdoor workers in Alberta?
2. What are the best practices for creating a sun exposure and skin cancer surveillance system for outdoor workers in Alberta?

To answer these two questions, this project report has two complimentary components. The first part (Section 4) reports on the measurements of solar UVR exposure in a group of Alberta's outdoor workers in order to benchmark the risk experienced in an area of high ambient UVR. The second part (Section 5) reports on the literature review and key informant interviews we performed to collect information on the surveillance of outdoor workers and their occupational health, specific to sun exposure. After evaluating these materials we provide a summary of the research overall, placing it in context for Alberta and suggesting some next steps for further research (Section 6).

Section 4: UVR measurement sub-study

The purpose of this first sub-study was to collect personal solar UVR exposure measurements from workers in Alberta and to assess which personal, work, and environmental factors are important determinants of personal daily solar UVR exposure.

4.1 Methodology

Study design

This cross-sectional study was conducted primarily in the province of Alberta, Canada during the summer of 2019. Personal solar UVR exposure measurements were collected from June through September. Workers were asked to wear an electronic UVR dosimeter for five consecutive working days, but shorter or longer participation was also permitted. Additionally, workers completed a questionnaire that collected demographic information, job characteristics, sun protection behaviours, and personal risk factors for skin cancer. Weather forecast parameters including temperature, humidity, wind conditions, and UV index were recorded daily from Environment Canada for each city/town [30].

Study sample

Recruitment was conducted by first contacting management or health and safety teams from building trade unions and employers primarily in the province of Alberta. A small number of participants in British Columbia and Saskatchewan were also included after they learned of the study via word of mouth. After a company consented to participate, outdoor workers, defined as those who regularly spend at least 2 hours outdoors per workday, were identified by their supervisors and invited to participate. Workers had to be 18 years of age or older, or if younger, have signed parental or guardian consent to participate. The study received ethical approval from the Health Research Ethics Board of Alberta – Cancer Committee (certificate HREBA.CC-18-0615).

Data collection

The personal UVR dosimeters used for the study were from Scienterra [31]. The dosimeter mechanism has been described elsewhere [31-33]. Briefly, these monitors can track temperature and the device's battery life, and they contain an analog-to-digital converter that measures the voltages produced by ultraviolet (UV) irradiance. UV irradiance is detected with aluminum-gallium-nitride photodiodes, which have a spectral response that is a close match to the erythemal action spectrum of human skin [34]. In order to convert the analog measurements into UV index measurements, the dosimeters were side-by-side calibrated with a gold-standard Brewer Spectrophotometer located in Stony Plain, Alberta [35]. The spectrophotometer measures spectral UV irradiation every 10 to 20 minutes during daylight hours. The dosimeters were programmed to take a UV measurement once per minute during the hours of 7AM and 5PM each day. Each per-minute measurement was converted to a UV Index value using the calibration curve (unique to each dosimeter), and the standard erythemal dose (SED_{day}) per day was calculated by summing the per-minute SED (SED_{minute}) by day, as per equations (1) and (2).

(1) $$SED_{day} = \sum 7\text{ am} - 5\text{ pm}\,[SED_{minute}]$$

(2) $$SED_{minute} = \frac{(UVIndex_{minute} * 0.025\text{Wm}^{-2} * 60\text{s min}^{-1})}{100\text{ Joules m}^{-2}}$$

where SEDday is the Standard Erythemal Dose per work day in Joules m−2; UV Indexminute is the UV Index (unitless) measured from the dosimeter badge per minute; 0.025 W m−2 is the standard unit for solar irradiance per unit of UV Index; and, 1 Joule = 1 Watt s−1 [36].

Workers were asked to wear their dosimeters for full work shifts over an entire sampling week(s) (5 sampling days) and were given the option of wearing it on their hardhat, pinned to their lapel, or on a wrist band (Figure 1); their selection of dosimeter location was recorded.

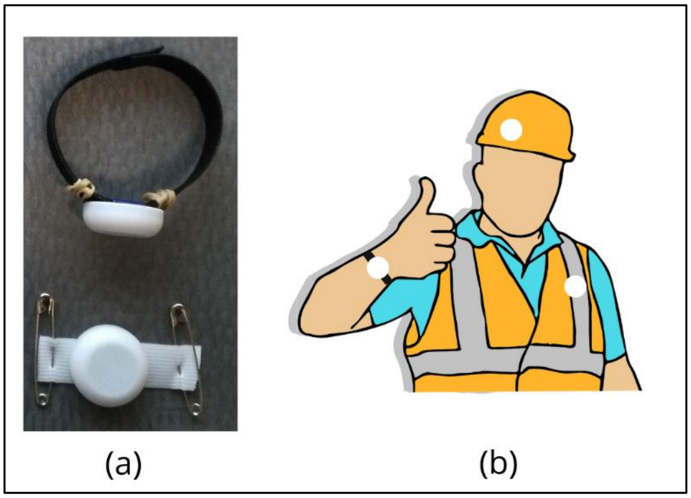

Figure 1. **a) The UVR dosimeters used (in wrist band and lapel-pinned configuration) and b) the placement options (hardhat, shoulder/lapel, or wrist) presented to the workers**

A paper questionnaire was administered to collect information on workers' sun habits, skin cancer risk factors, jobs, and demographics. Workers were asked to return the completed questionnaires to the study coordinator either in person or via email after their sampling period was complete. A copy of the questionnaire is included in Appendix 1. The coordinator was on site to clarify any questions at the beginning and end of each sampling period.

Variables and statistical analysis

Demographic variables included in the analysis were age, sex, education, ethnicity, city/region or latitude, and job title. Workers' jobs were categorized into five groups based on their self-reported job titles by an occupational hygienist: 1) trades (e.g. carpenters, bricklayers, concrete labourers, foremen, electricians, plumbers); 2) recreation (e.g. coaches, dog walkers, paddling instructors); 3) landscape/maintenance services (e.g. golf course maintenance workers, clubhouse servers, grounds keepers, parks labourers); 4) security (e.g. campus security, equipment technicians, parking enforcement, parking officers); and 5) professional services (e.g. mail delivery agents, project coordinators, fish and wildlife specialists, industrial hygienists).

Self-reported skin cancer risk factors were collected and analyzed, including history of blistering sunburn during childhood, family history of skin cancer, number of burns in the previous summer, hair colour (red/blonde, dark blonde/light brown, or dark brown/black), eye colour (blue/green/grey, hazel/light brown, and dark brown/black), and skin type. Workers' skin types were categorized by the researchers according to the Fitzpatrick skin types [37]; light to fair skin types were classified as Fitzpatrick types I and II, white to olive skin types were classified as Fitzpatrick III and IV, while olive to dark brown skin types were classified as Fitzpatrick V-VI. Analyses also considered forecast (sunny, cloudy, and mixed), hours worked outside, and dosimeter placement (hardhat or lapel/wrist). Lapel and wrist placements were grouped since too few workers selected the wrist placement. Basic descriptive statistics were calculated for all variables (means, standard error, ranges). Mean SED_{day} and standard errors, corrected for repeated measures, were generated using PROC MIXED. Bivariate analyses between the variables and SED_{day} were conducted; each covariate was modelled independently and individually, with untransformed Total SED as the response variable. In addition, descriptive statistics (mean SED, range, and standard deviation) were calculated by trade and two hour windows (7:00-8:59, 9:00-10:59, 11:00-12:59, 13:00-14:59, 15:00-17:00). An ANOVA analysis was conducted to assess variations in SED across time windows and trade.

Workers' mean solar UVR doses were compared with the International Commission on Non-Ionizing Radiation Protection (ICNIRP) threshold limit guideline of 30 Jm^{-2} (corresponding to 1.0-1.3 SED) [38]. Results were presented in categories relative to the upper limit of this guideline (1.3 SED), and by trade (categories: <1.3 SED, and 1-2 times, >2-4 times, >4-10 times, and >10 times the guideline).

Actual maximum ultraviolet index (UVI) and maximum available UV dose were calculated using data from the Brewer Spectrophotometer for the city of Edmonton alone, as it is located closest to the Stony Plain Brewer Spectrophotometer (it cannot be assumed that the daily maximum available UV dose was the same for locations further from Stony Plain). Brewer data were downloaded for each study day. To calculate the maximum available UV dose, the SED accumulated per minute was calculated by integrating forward in time from the measurements that are collected every 10 to 20 minutes, with the assumption that the UV Index remains the same over that span. These per-minute values were then summed to obtain the maximum daily dose. Spearman rank correlation coefficients were calculated to characterize the agreement between forecasted and actual maximum UVI, and between forecasted maximum temperature and UVI for Edmonton. We chose Spearman correlation coefficients over Pearson correlation coefficients due to the bounded nature of UVI.

To account for any outliers that may have arisen due to static discharge, which can occasionally occur due to the dry Albertan climate, we implemented an outlier detection algorithm using the interquartile range of UVI values. For any given calendar date, the interquartile range of the UVI readings from every minute-by-minute dosimeter reading of every person in the study who wore the dosimeter on that date was calculated. Then, using formula (3) below as our threshold for removal, any minute-by-minute UVI reading that was above this threshold was overwritten to zero and assumed to be a potential "misfire" by the dosimeter. The result of implementing this algorithm is that, on a day-by-day basis, the maximum UVI readings that each dosimeter yielded are now much more likely to reflect the true UVI exposure rather than a false exposure value due to static discharge by the dosimeter.

$$Threshold = 3rd\ Quartile + (1.5 \times Interquartile\ Range) \tag{3}$$

Dosimeters that yielded a total SED reading of exactly zero for a given day were removed from the study since these readings indicated that the badges were incorrectly donned or not worn at all (n=20, corresponding to three workers that were excluded); these were considered idle days. An idle day was further defined to consist of any dosimeter reading that yielded a total SED reading below the 5th percentile of all total SED values in the study (0.026 SED). As a result, any dosimeter which yielded a total SED reading that was below this threshold was also excluded (n=30 days). Workers who only had readings below the threshold were likewise excluded from the study population. (n=1 worker)

We used SAS PROC MIXED to control for repeated measures per person and per calendar day, and to create marginal models assessing the determinants of sun exposure. Variables that were offered to the first model were: ethnicity, sex, education, history of childhood sunburn, family history of skin cancer, skin type, eye colour, hair colour, trade, city/region, dosimeter placement, age, hours of work outside, forecast, and number of burns in the previous summer. In the second model, city/region was replaced with latitude. Variables included in the final model were restricted using a manual backwards stepwise regression method, in which variables where p>0.20) were sequentially removed until the best fitting model was found using the Akaike Information criterion (AIC).

4.2 Results

Demographics and skin cancer risk factors

In total, 192 workers were recruited for the study. Measurements were collected over a consecutive 106 day period (June 4 to September 17, inclusive) for a total of 982 person-days in which a dosimeter was worn. On average, dosimeters were worn for 5.13 days. After excluding zero-SED and idle days (n=50), 188 workers remained in the study, accounting for 932 measurement days (days for which a dosimeter was worn). These were worn for 4.96 days per worker, on average. After excluding workers with missing or implausible ages for the modelling analysis, 179 workers remained corresponding to 883 measurement days.

Participants were mostly male (75%), Caucasian (75%), young (mean 37 years), and mostly from the cities of Edmonton (44%) or Calgary (44%) (Table 1). Other cities/regions from which samples were collected (n=22) are Red Deer (6% of the total sample), Southern Alberta (1%), Central Alberta (2%), Kelowna (a city in British Columbia, 2%), and Saskatchewan (1%). The majority of participants worked in the trades (46%), followed by landscape/maintenance services (29%). On average, the workers spent 4.8 hours outdoors while at work. Only 31% of workers reported light to fair skin but approximately two thirds of workers experienced at least one sunburn in the preceding summer (Table 1).

Table 1. Descriptive statistics and personal solar ultraviolet radiation monitoring results by potential determinant of exposure

Covariate	**N**	**SED_{day} (SE)**	**Range**
Overall (uncorrected)	883 days	1.96 (0.08)	0.03 – 16.63
	Corrected for Repeated Measures		
Categorical variables	**N (%)**	**SED_{day} (SE)**	**P-Value**
Overall			
All subjects	179	1.93 (0.13)	.
Ethnicity (Missing=1)			
Caucasian/White	134 (75)	2.00 (0.15)	0.29
Asian	23 (13)	1.36 (0.38)	
Other	21 (12)	1.95 (0.40)	
Sex (Missing=1)			
Male	133 (75)	2.00 (0.15)	0.39
Female	45 (25)	1.74 (0.27)	
Education (Missing=7)			
Completed college	65 (38)	1.56 (0.22)	< 0.01
Some college	60 (35)	1.73 (0.23)	
High school or less	47 (27)	2.65 (0.25)	
Childhood sunburn (Missing=3)			
Yes	99 (56)	1.88 (0.18)	0.70
No	77 (44)	1.99 (0.21)	

Covariate	N	SED_{day} (SE)	Range
Family history of skin cancer (Missing=1)			
Yes	24 (13)	1.84 (0.36)	0.91
No	145 (81)	1.94 (0.15)	
Don't know	9 (5)	2.15 (0.62)	
Skin type[1] (Missing=11)			
Light to fair (I – II)	52 (31)	1.98 (0.25)	0.92
White to olive (III-IV)	72 (43)	1.85 (0.21)	
Olive to dark brown (V-VI)	44 (26)	1.93 (0.28)	
Eye colour (Missing=0)			
Blue/green/grey	90 (50)	1.99 (0.19)	0.76
Hazel/light brown	30 (17)	2.01 (0.33)	
Dark brown/black	59 (33)	1.79 (0.23)	
Hair colour (Missing=0)			
Red/blonde	31 (17)	3.01 (0.30)	< 0.01
Dark blonde/light brown	64 (36)	1.64 (0.22)	
Dark brown/black	84 (47)	1.72 (0.19)	
Trade (Missing=0)			
Trade worker	82 (46)	1.90 (0.19)	< 0.01
Recreational worker	12 (7)	1.84 (0.49)	
Landscape/maintenance services	52 (29)	2.64 (0.23)	
Security worker	17 (9)	0.73 (0.42)	
Professional services	16 (9)	0.81 (0.46)	
City/Region (Missing=0)			
Calgary	78 (44)	2.14 (0.19)	0.02
Edmonton	79 (44)	1.52 (0.20)	
Other	22 (12)	2.60 (0.37)	
Dosimeter placement (Missing=0)			
Lapel/watch	152 (85)	1.61 (0.13)	< 0.01
Hardhat	27 (15)	3.59 (0.30)	
Forecast[2] (Missing=0)			
Sunny	184 (21)	1.87 (0.12)	< 0.01
Mixed	467 (53)	2.23 (0.13)	
Cloudy	232 (26)	1.46 (0.15)	
Continuous variables	**Mean (range)**	**β (SE)[3]**	**P-Value**
Age (in years; Missing=0)	37 (14-70)	0.004 (0.01)	0.64
Number of burns the previous summer (Missing=15)	1.6 (0-5)	0.21 (0.08)	0.01
Hours outside at work (Missing=3)	4.8 (1-6)	0.47 (0.09)	< 0.01

[1]Skin type categories and values correspond to the Fitzpatrick scale [37]

[2]The frequency counts and % for f1orecast correspond to each sampled *day* (n=883) rather than each sampled *person* (n=179)

[3]Beta denotes the estimated adjusted average increase in SED_{day} associated with a 1-unit increase in the corresponding continuous variable

Meteorological results

The data collection period (June 4 to September 17) mostly experienced mixed sunny/cloudy weather (78 days), followed by cloudy and sunny days (68 and 41 days, respectively) (Table 2). The mean, maximum forecasted temperature over the data collection period ranged from 17.3 °C on cloudy days, to 23.6°C on sunny days. Similarly, the forecasted maximum UVI was lowest on cloudy days (4.8) compared to sunny (6.6) and mixed days (6.8). Brewer spectrophotometer data were available for Edmonton alone. Agreement between the forecasted and actual maximum UVI for Edmonton was strong and statistically significant for sunny (Spearman coefficient=0.93, p<0.01), mixed (0.70; p-value<0.01), and cloudy days (Spearman coefficient=0.56, p<0.01). Agreement between the forecasted maximum temperature and UVI was statistically significant among sunny (0.80; p-value<0.01) and cloudy days (0.50; p-value=0.01), but not for mixed days (0.28, p=0.13).

Table 2. Forecasted and observed UVI, UV dose, and temperature, by region and forecast

Region	Forecast	N Days (%)	Forecasted maximum UVI (mean, SD)	Actual maximum UVI (mean, SD)*	Maximum available UV dose (SED) (mean, SD)*	Maximum forecasted temperature (mean, SD)
Edmonton	Sunny	12 (16.7)	6.3 (1.1)	5.4 (1.1)	27.3 (7.7)	23.0 (3.8)
	Mixed	31 (43.1)	6.5 (1.3)	5.8 (1.2)	27.3 (8.2)	20.8 (2.4)
	Cloudy	29 (40.3)	4.1 (1.6)	4.4 (1.9)	16.0 (7.0)	16.7 (3.2)
Overall	Sunny	41 (21.9)	6.6 (1.4)	n/a	n/a	23.6 (5.0)
	Mixed	78 (41.7)	6.8 (1.2)	n/a	n/a	21.8 (3.6)
	Cloudy	68 (36.4)	4.8 (1.8)	n/a	n/a	17.3 (4.2)

*Actual maximum UVI and available dose were calculated for Edmonton alone, which is where the Brewer Spectrophotometer is located

Ultraviolet radiation dosimetry results

The exposure measurements (SED_{day}) were log-normally distributed. The mean SED_{day}, uncorrected for repeated measures, was 1.96 (SE=0.01), and the corrected mean SED_{day} was 1.93 (SE= 0.13). Overall, the measurements ranged from 0.03 to 16.63 (Table 1).

Mean and maximum SED were highest from 11:00-12:59 and 13:00-14:59, over all trades (Table 3). Variations in SED by trade, time increment, and their interaction were highly significant (p<0.0001; ANOVA results not shown). The range in exposure was lowest in the earliest time increment (0.00-1.66 SED) and largest from 13:00-14:59 (0.00-6.29 SED).

Solar UV exposure differed by education, showing a pattern of decreasing exposure with increasing levels of education (Table 1). Exposure also differed by hair colour, with workers who had lighter hair colour being exposed to higher levels. The strongest relationships (p<0.01) were observed between SED_{day} and trade, city, forecast, and dosimeter placement. Workers in landscape and maintenance services, as well as trade and recreational workers were exposed to levels two to four times the average exposure experienced by security workers and professional services. Exposure levels varied by city/region, with workers in the "other" cities/regions experiencing the highest average levels (2.60 SED), followed by Calgary (2.14 SED), and Edmonton (1.52 SED). In particular, Red Deer appeared to have the highest average SED levels of the other cities/regions (4.02 SED). However, due to large standard errors resulting from small sample sizes, the "other" cities/regions were grouped here and in the modelling analyses, below. Exposure on mixed days was highest (2.23 SED) when compared to cloudy and sunny days (1.46 and 1.87 SED, respectively). Finally, mean exposure measurements were more than double when the dosimeters were placed on hardhats compared to the lapel/watch placements.

Table 3. SED exposure by time window and trade

Time	Statistic	All Trades	Trade Worker	Recreational Worker	Landscape/ Maintenance Services	Security Worker	Professional Services
7:00-8:59	N	825	411	23	276	78	37
	Mean	0.12	0.08	0.05	0.23	0.06	0.02
	Std. Dev	0.22	0.14	0.07	0.31	0.14	0.04
	Min	0.00	0.00	0.00	0.00	0.00	0.00
	Max	1.66	1.66	0.22	1.61	0.64	0.18
9:00-10:59	N	921	451	57	288	78	47
	Mean	0.47	0.33	0.75	0.74	0.24	0.19
	Std. Dev	0.68	0.46	0.70	0.93	0.43	0.19
	Min	0.00	0.00	0.00	0.00	0.00	0.00
	Max	4.99	3.43	2.85	4.99	1.85	0.76
11:00-12:59	N	915	452	56	280	80	47
	Mean	**0.61**	**0.47**	**0.67**	**0.99**	**0.22**	**0.36**
	Std. Dev	0.95	0.64	0.66	1.38	0.44	0.35
	Min	0.00	0.00	0.00	0.00	0.00	0.00
	Max	9.14	5.61	3.43	9.14	1.71	1.43
13:00-14:59	N	931	449	61	270	104	47
	Mean	0.53	0.44	0.59	0.76	0.40	0.29
	Std. Dev	0.81	0.57	0.57	1.13	0.88	0.30
	Min	0.00	0.00	0.00	0.00	0.00	0.00
	Max	6.29	4.86	2.79	6.29	4.67	1.34
15:00-17:00	N	758	428	49	124	104	53
	Mean	0.25	0.31	0.40	0.12	0.12	0.19
	Std. Dev	0.45	0.51	0.50	0.37	0.26	0.28
	Min	0.00	0.00	0.00	0.00	0.00	0.00
	Max	4.99	4.99	1.93	3.38	1.89	1.68

Table 4 compares the study measurements to the internationally recommended occupational exposure limit guideline (1.3 SED). Overall, approximately half of the measurements were above the recommended guideline. Security workers and professional services had the lowest levels of UVR exposure, with approximately 77% and 75% of measurements falling below the international occupational exposure limit guideline, respectively, while landscape and maintenance services had the highest levels of exposure followed by trade workers, with 30% and 23% of measurements exceeding double the guideline, respectively.

Table 4. Distribution of the personal solar UVR measurements (%) by multiples of the recommended occupational exposure limit guideline (1.3 SED)

Trade	**< guideline (%)**	**1-2x guideline (%)**	**>2-4x guideline (%)**	**>4-10x guideline (%)**	**>10x guideline (%)**
Trade worker	220 (54.5)	92 (22.8)	74 (18.3)	15 (3.7)	3 (0.7)
Landscape and maintenance services	141 (50.0)	53 (18..8)	31 (11.0)	52 (18.4)	5 (1.8)
Security worker	67 (77.9)	5 (5.8)	9 (10.5)	5 (5.8)	0 (0.0)
Professional services	38 (74.5)	12 (23.5)	1 (2.0)	0 (0.0)	0 (0.0)
Recreational worker	27 (45.0)	12 (20.0)	18 (30.0)	3 (5.0)	0 (0.0)
Overall	*493 (55.8)*	*174 (19.7)*	*133 (15.1)*	*75 (8.5)*	*8 (0.9)*

Estimated coefficients for the final multivariable marginal model are summarized in Table 5. A separate model incorporating latitude instead of city/region was also performed; however, only model results with city/region are presented since latitude was not as strong of a predictor of solar UVR exposure (p>0.20). All other available variables were presented to the model. Ethnicity, age, eye colour, skin type, sex, family history of skin cancer, number of sunburns the previous summer, and presence of childhood sunburns were removed in the backward selection process, in order from least to most significant. In the final model, hair color, education, trade, city, dosimeter placement, forecast, and number of hours outside at work remained significant determinants of solar UV exposure (p<0.20), of which trade, dosimeter placement, forecast, and number of hours outside at work were statistically significant (p<0.05) (Table 5; see Appendix 2 for an explanation of how to interpret model findings).

4.3 Discussion

Overall context

This study builds on previous research to better quantify solar UVR exposures among Canadian workers. Consistent with peak ambient UVR in Canada, peak exposure among this group of workers occurred between 11:00 and 15:00. However, our results indicate that even within a geographically constrained area, exposure to solar UVR among outdoor workers is highly variable, with exposure ranging from 0.03 to 16.63 SED. These findings are similar to those in a study of outdoor workers in the Vancouver area, where workers were exposed to mean levels of 1.08 SED (ranging from 0.01 to 19.2 SED) [36]. However, the results are more variable compared to those from a study of construction workers in Romania, where daily doses ranged from 1.28 to 6.4 SED [39], and our results are lower compared to a study of outdoor workers spanning three Canadian provinces (mean exposure of 6.1 SED, ranging from approximately 0 to 26.5 SED) [40]. The differences in exposure across these studies may be the result of the jobs that were included; for example, the study assessing exposure across the three Canadian provinces focused on a subset of workers (utility and municipality workers), where overall exposure may be higher compared to the broader groups included in our study. Many other workplace solar UVR measurement studies have been conducted across the world, including countries with comparable latitudes to Canada. However, comparing overall exposure measurements across jurisdictions and studies is difficult, given the multitude of factors that influence solar UV exposure, such as differences in time spent outdoors, work tasks, altitude, latitude, etc. [1, 41, 42], in addition to differences in study design and measurement methods.

Table 5. Model results: predictors of SED_{day} (Standard Erythemal Dose per day)

Predictor	Coefficient (SE)	P-Value
Intercept	-1.29 (0.32)	< 0.01
Education (p = 0.043)		
High school or less	0.29 (0.17)	0.09
Some college	-0.14 (0.16)	0.41
Completed college	0 (Ref.)	
Hair colour (p = 0.111)		
Dark brown/black	-0.07 (0.15)	0.66
Red/blonde	0.33 (0.20)	0.10
Dark blonde/light brown	0 (Ref.)	
Trade (p = 0.003)		
Landscape/maintenance services	-0.03 (0.17)	0.84
Professional services	-0.54 (0.28)	0.05
Recreational worker	0.18 (0.28)	0.53
Security worker	-0.97 (0.26)	< 0.01
Trade worker	0 (Ref.)	
City/Region (p = 0.028)		
Edmonton	0.12 (0.16)	0.45
Other	0.65 (0.24)	0.01
Calgary	0 (Ref.)	
Dosimeter placement (p = 0.022)		
Hardhat	0.47 (0.20)	0.02
Lapel/watch	0 (Ref.)	
Forecast (p < 0.001)		
Cloudy	-0.75 (0.11)	< 0.01
Mixed	0.03 (0.10)	0.78
Sunny	0 (Ref.)	
Number of hours outside at work (p < 0.001)		
Continuous variable	0.26 (0.05)	< 0.01

P-values listed with the covariate headers indicate the significance of their Type III Tests of Fixed Effects, i.e. overall significance in the model.

Dosimeter placement in our study had a significant effect on solar UVR measurements, with hardhat placements having a statistically higher mean SED_{day} compared to the lapel/watch placement. This was expected, since hardhat dosimeters are more likely to be exposed to the sun regardless of position compared to the wrist and lapel dosimeters, which may become obscured depending on the positioning of workers' bodies. Similar findings were observed in a Canadian sampling study conducted by Peters et al. (2016) as well as studies that have more systematically assessed the impact of dosimeter placement on exposure level by collecting measurements from multiple body locations [13, 43]. In these, the average solar UVR exposure was highest when the dosimeters were placed near the head area compared to other body parts, and individual level factors such as posture, movement of the body, and orientation towards the sun highly influenced exposure. After controlling for other variables, the badge placement effects were still statistically significant in our model results, indicating that future studies should at the very least consider dosimeter placement in the study design and analysis. In solar UVR monitoring studies, allowing workers to select the dosimeter placement (according to comfort and feasibility) will be instrumental in maximizing participation rates. Despite the observed differences, the mean exposure levels among both the hardhat and the lapel/watch dosimeter placement groups were higher than the international occupational exposure limit guideline, indicating that either can be important when assessing workers' solar UV dose.

The UVR exposure among workers from the "other" cities/regions was higher compared to the Calgary workers in a statistically significant manner in the bivariate and combined analyses. This may partly be explained by differences in dosimeter placement and trade. There was a greater relative proportion of workers who wore the dosimeters on their hardhats and who worked in landscaping and maintenance, which experienced the highest exposure levels, in the "other" regions compared to Calgary. After controlling for covariates in the marginal model, a regional effect persisted with workers from the "other" city/regions experiencing significantly elevated exposures compared to Calgary. Levels appeared to be highest among the workers in Red Deer, specifically; but, given the small sample size and large variability in the measurements, additional samples should be collected across sites to determine if the regional effect is real. Potential contributors to the regional/city variation include differences in sun protection behaviours and latitude. However, latitude was not a significant predictor of solar UVR exposure in the marginal model and there were no apparent differences in sun protection behaviours by city/region, indicating that if the regional effect persists after additional sampling, there may be other factors influencing solar UVR exposure among this group of workers.

Forecast and trade were strong predictors of solar UVR exposure. As expected, workers were exposed to the lowest levels of solar UVR on cloudy days. However, interestingly, the highest levels of solar UVR were observed on mixed days. These results differed from the model results presented in a Vancouver study, in which solar UVR exposure decreased progressively from sunny to mixed and cloudy days [36]. Differences in sun protection behaviours by forecast may partly explain the difference; while sunny days generally offer more opportunity for exposure, workers may better engage in sun protection behaviours on sunny days compared to mixed days [44]. By trade, security workers and professional services experienced a lower dose compared to trade workers, which can be explained by the fact that security workers and professional services are more likely to include indoor work or to have more readily available shade structures. Higher doses were observed among landscape/maintenance services workers overall. However, this is likely due in part to the larger proportion of landscape/maintenance services workers who wore the dosimeters on their hardhats compared to the other trades. After controlling for the other covariates in the predictive model, the landscape/maintenance services workers and trade workers did not differ significantly and in fact, landscape/maintenance services workers were associated with a lower overall dose compared to trade workers.

Strengths

The size of the study is a major strength. With over 850 full-day measurements collected from 179 workers, this is the largest study in terms of measurements collected in Canada. This, in combination with the demographic, job, and sun protection behavior information that was collected, allowed for a detailed analysis of numerous predictors of solar UVR exposure among outdoor workers with sufficient power to detect statistically significant findings. Even so, there was a paucity of data within certain groups (i.e. only four workers wore the dosimeters on their wrists), leading to the inability to properly assess the contribution of some factors, such as dosimeter placement, on measured exposure. In the future, efforts should be taken to ensure adequate samples are collected across the dosimeter placement groups so that the impacts of dosimeter placement in real life settings can be effectively assessed. However, studies solely looking to assess workers' exposures should accommodate workers' preferred placements in order to capture their main exposure site, as determined by the worker, and to account for different uses of personal protective equipment across work settings (e.g. some workers may not wear hardhats).

The study used electronic dosimeters, allowing for the collection of multiple samples over a working week and a more accurate indicator of workers' average exposure over the summer months. Polysulfone badges have commonly been used by researchers in this area since their introduction in the late 1970s [45]. However, these may be cumbersome for workers to use over longer durations because the polysulfone badges must be kept in complete darkness outside of the sampling period. The electronic badges used in this study were simple for workers to use, making it more feasible to collect exposure measurements over a full workweek or longer. Although the function of the electronic dosimeters have not yet been compared with polysulfone badges, they both use the same principles for measuring solar UVR exposure and were calibrated with similar instruments and weighting functions [31, 33].

Limitations

There are a number of limitations that should be noted. Employers were not randomly selected for inclusion in the study, and employers were asked to identify employees for participation in the study, leaving the study open to selection bias. Because the participating workplaces and workers may have different characteristics compared to those who did not, the findings may not be applicable to the broader population of outdoor workers in Alberta. However, conducting a study with randomly selected workers is not feasible in many exposure monitoring studies and care was taken to minimize potential for selection bias. For example, employers were asked to identify and invite all workers that spent greater than two hours outdoors during their work shifts. As previously mentioned, we were unable to estimate the contribution of the wrist dosimeter placement on solar UVR dose due to a low sample size. In the future, special consideration of the dosimeter placement must be taken, based on the study purpose. Finally, samples were only collected over the summer months. The summer of 2019 was much less sunny than is typical for Alberta and additional sampling to characterize outdoor workers' typical summertime exposure to solar UV in Alberta is needed. Although solar UVR exposure over the winter months is likely minimal in the cold Canadian winters because workers are more likely to be covered and because the daylight hours are shorter, studies assessing winter time exposures (and albedo effects due to snow coverage) in Canada have not been conducted. More work should be done to understand how solar UVR exposure may differ in the winter across Canada.

Knowledge translation completed and in progress

We have created several knowledge products in relation to this study, and have some more work planned that will continue post-project.

1. Webinar
    - We advertised and hosted a webinar on February 27, 2020 to share the results of both the measurements and the monitoring sub-study. Approximately 80 people attended

the webinar, which had a lively Q&A period. A post-webinar survey was sent out which was filled out by 14 participants (a copy of the survey results is included in Appendix 3).

2. Reports to workers and managers
   - Confidential personalized results reports were shared with workers who provided contact information, and a summary report was provided to employers with at least five staff members participating in the study. No information for individual workers was provided to employers, only summary data. For employers with less than five staff in the study, a broad report with results of the study overall was provided.
3. Scientific paper submitted
   - We submitted a paper containing the results of this sub-study to the journal *Environmental Research* in May 2020. We received a minor revision request from the journal's editor, and have since made the requested edits and resubmitted the paper for publication on June 29, 2020. The paper is titled "Solar ultraviolet radiation exposure among outdoor workers in Alberta, Canada" and was authored by Ela Rydz, Andrew Harper, Brandon Leong, Victoria Arrandale, Sunil Kalia, Lindsay Forsman-Phillips, D. Linn Holness, Thomas Tenkate, and Cheryl Peters.
4. Work on sun protection behaviours
   - We decided to use other data collected in the study (but not related to the research questions posed by this grant project) to examine which sun safety behaviours the workers in our study were engaging in, and whether or not these differ by their working versus leisure time. The analysis for this paper is now complete and we are writing it up for submission to a journal (expected submission, August 2020).
5. Abstract: 5th International UV and Skin Cancer Conference (Belgium)
   - This conference was originally scheduled for May, 2020, but has since been postponed to May, 2021. We have an accepted abstract based on the UVR sub-study entitled: "Solar ultraviolet radiation exposure among outdoor workers in Alberta, Canada." We will share the results of the study at that time (barring any further postponements). https://uvandskincancer2020.org/
6. Web presence: CAREX Canada website and Sun Safety at Work Canada
   - As soon as results are completely final (i.e. two primary results papers have gone through peer review), we will update the current project page (https://www.carexcanada.ca/special-topics/sun-safety/) as well as create a study page on the Sun Safety at Work Canada website (https://sunsafetyatwork.ca/). We are currently working with partners to develop visually-appealing content for this purpose. We anticipate this will go live in fall 2020.

Section 5: Monitoring sub-study

The purpose of this second sub-study was to investigate via a literature review and key informant interviews whether occupational surveillance has been conducted for outdoor workers previously, to identify the key planning components for structuring an effective occupational surveillance program and to better understand the best practices for the design and implementation of a potential surveillance system for outdoor workers.

5.1 Methods

Methodology for best practices in surveillance/literature review

As part of this second sub-project a literature review was conducted in order to determine whether occupational surveillance has been conducted for outdoor workers previously and to identify the key planning components for structuring an effective occupational surveillance program. The literature review included searches of both scientific and grey literature. An Alberta Health Services (AHS) librarian was consulted to help with designing effective search strategies. For the scientific literature search, a search strategy was developed combining the following four concepts: occupational surveillance/ outdoor workers; occupational disease or exposure/outdoor workers; occupational surveillance and outdoor workers/solar UVR; best practices for occupational surveillance. Several scientific databases were searched (MEDLINE, PubMed, Web of Science and Scopus), and the search strategy was adapted to each of them. The snowballing search technique was also used to find additional references from the bibliographies of the most cited relevant articles and documents. In order to identify relevant grey literature sources Google and Google Scholar were used, as well various countries' occupational hygiene/health and safety organizations were consulted. The results of the literature search have been saved in an EndNote database.

After reviewing the searched literature it became clear that there is no literature available that focusses specifically on occupational surveillance systems for outdoor workers. To obtain a better understanding of occupational surveillance systems it was necessary to look beyond only outdoor workers and to include surveillance systems that focus on various occupational diseases (ODs) that workers may be diagnosed with, or exposures they may experience.

The main criteria for literature inclusion in the "Table of Surveillance Practices" (Appendix 4) are: 1) articles/reports that describe an occupational surveillance system and include either guidelines/description on how it was designed or functions, 2) articles/reports that describe some of the barriers/challenges (limitations) as well as facilitators (strengths) of the surveillance system, and 3) articles/reports that focus on the inclusion of NMSC as an occupational disease.

There were two specific aims for the literature retrieved: the first aim was to obtain a better understanding of the various types of occupational surveillance systems or strategies that exist (country of origin, what is the type of surveillance or surveillance strategy, what types of exposures/outcomes does it include). The second aim was to determine whether the described system can be applied to outdoor workers with a primary focus on NMSC.

Methodology for key informant interviews

22 telephone interviews were conducted between August 28, 2019 and January 8, 2020 to better understand the best practices for the design and implementation of a potential surveillance system for outdoor workers and the barriers and facilitators to creating, managing and ensuring the ongoing success of a potential occupational surveillance system for outdoor workers. Participants were chosen based on the following criteria:

1. Canadian representation, with emphasis on jurisdictions that have experience designing or implementing occupational surveillance systems and/or expertise in skin cancer prevention/sun safety programs
2. International perspective, with emphasis on jurisdictions that have well-established/strong experience designing or implementing occupational surveillance systems and/or expertise in skin cancer prevention
3. Inclusion of a broad spectrum of stakeholders (i.e., regulators, researchers, physicians)

The interviews ranged from 35 minutes to 60 minutes in length and were conducted by one member of the study team. The interviews were recorded, transcribed, and analyzed for common themes. The interview component of the study received ethical approval from the Cancer Committee of the Health Research Ethics Board of Alberta (certificate #18-0615). For further reference refer to the interview questions in Appendix 5.

Of the 22 interviews, 11 were with individuals working within Canada and 11 were with individuals from other countries. Also 13 of the interviewees had direct experience with occupational surveillance systems and 9 had specific experience with skin cancer prevention programs (or research).

The interviewees represented the following jurisdictions:

- **Alberta:** Ministry of Labour and Immigration; Alberta Health Services (2)
- **British Columbia:** WorkSafeBC (2)
- **Ontario:** Ministry of Labour; Occupational Cancer Research Center (OCRC) (2); Canadian Dermatology Association
- **Saskatchewan:** Saskatchewan Cancer Agency
- **Nova Scotia:** Nova Scotia Health Authority Cancer Care Program; Nova Scotia Department of Labour and Advanced Education; Sun Safe Nova Scotia Coalition
- **United Kingdom:** University of Manchester
- **The Netherlands:** Academic Medical Center Amsterdam
- **Norway:** Norwegian Labour Inspection Authority
- **Italy:** University of Modena
- **Germany:** Deutsche Gesetzliche Unfallsvesicherung (DGUV); University of Osnabrueck
- **Australia:** QIMR Berghofer; University of Sydney
- **USA:** The National Institute for Occupational Safety and Health (NIOSH); Centers for Disease Control and Prevention (CDC); Safety and Health Assessment and Research for Prevention (SHARP)

5.2 Results (1): Outcome of the literature review

What is surveillance?

Surveillance is defined by the CDC as "the ongoing, systematic collection, analysis, and interpretation of health data, essential to the planning, implementation and evaluation of public health practice, closely integrated with the dissemination of these data to those who need to know" [46]. The purpose of surveillance systems for occupational health and safety is to "provide(s) the data and analyses needed to understand the relationships between work and injuries and illnesses in order to improve worker safety and health and prevent work-related injuries and illnesses" [17]. Typically surveillance starts with planning and designing the system, collecting the data, organizing and managing the data, analyzing the data, interpreting the results, then communicating the information to the groups of people who need to know [47]. The final task of a surveillance system is to guide policy or help to put interventions or prevention programs in motion [17].

In Canada there is no national single all-encompassing occupational surveillance system or systematic process for surveillance, but instead occupational health and safety (OHS) is a provincial responsibility in which provinces design their own occupational surveillance schemes to accomplish specific surveillance objectives [48]. Occupational surveillance systems have strengths and weaknesses and in North America they focus for the most part on health outcomes as opposed to specific hazards and exposures [17]. Work-related disease or occupational disease information (as opposed to injury) has not been included in most occupational surveillance schemes in Canada. Recently, however, Ontario has developed the Occupational Disease Surveillance System (ODSS) with the goal of providing trends in occupational disease [49].

Why is surveillance of outdoor workers important?

Outdoor workers are exposed to numerous workplace hazards. These hazards or exposures place the outdoor worker at risk for a wide variety of negative health outcomes, including cancers, heat stress and hypothermia, respiratory diseases, skin problems, infections, and physical injuries (for example from falls, equipment, or animals). In particular solar UVR is a substantial risk factor for outdoor workers and has been underestimated if not neglected as an occupational risk [1]. Since 1992 the International Agency for Research on Cancer (IARC) has deemed solar radiation as carcinogenic to humans (group 1) [50] and in 2012 IARC reviewed solar radiation and UV radiation and deemed UV emitting tanning devices as well as UVA, UVB and UVC as carcinogenic to humans (group 1) [51]. NMSC is the most diagnosed type of cancer and solar UVR is the main cause of NMSC in fair skinned people [52]. There is an increasing body of research linking solar UVR exposure in outdoor workers to the increasing incidence of NMSC [53, 54]. In various countries and regions exposure measurements (using personal dosimeters) of outdoor workers show high exposures to UVR compared with the general public [53]. Due to this very real risk to outdoor workers it is important that this at-risk group of workers be monitored or surveilled to ensure that proper primary prevention strategies are in place to minimize the risk of developing NMSC, to ensure that disease is caught at an early stage and to ensure that incidences of NMSC in outdoor workers are tracked. This can be done via an occupational surveillance program that focusses on outdoor workers and NMSC.

Key outcome

A key outcome of the literature review was that we found that no countries have designed or implemented an occupational surveillance system focused solely on outdoor workers. Some countries have developed surveillance systems that include NMSC and/or skin diseases (for e.g. EPIDERM), however, many countries do not include NMSC or sun exposure in their occupational surveillance systems or if it is included incidences or exposures are not reported regularly [54-59]. This may be for various reasons including that NMSC is not recognized as an OD, NMSC is rarely captured in cancer registries, it is a disease that has a long latency, doctors do not always link the cause of NMSC to work, there is limited understanding of the risk that solar UVR puts on outdoor workers and NMSC is simply too common and difficult to keep track of.

To obtain a better understanding of occupational surveillance systems, five surveillance strategies (exposure registry, disease registry, disease screening/medical surveillance, sentinel event surveillance and disease surveillance via data linkage) were consulted. These five surveillance strategies were most prevalent in the literature (as summarized in the Table of Surveillance Practices (Appendix 4)) and for this reason were examined in greater detail. These strategies have been used in various countries around the world, often have a long history of being utilized, and have strengths and weaknesses and could potentially be used for outdoor workers/NMSC. The five strategies can be defined as being either an occupational disease surveillance method or an occupational exposure surveillance method. Occupational disease surveillance involves “the systematic monitoring of health events in working populations in order to prevent and control occupational hazards and their associated diseases and injuries” [60]. Occupational exposure or hazard surveillance recognizes, collects and assesses information about work processes or workers exposed to a high level of exposure or risk in particular industries or job categories [61].

In Tables 6 and Table 7 the five surveillance strategies are described with a short definition, strengths, limitations, a current example, characteristics of this example and whether the strategy could be applicable to NMSC or solar UVR. Of interest is the fact that each strategy has strengths and limitations and cannot perfectly accomplish all surveillance goals. The common limitation among the 5 strategies is the underreporting of OD or the under-participation of physicians or workers in the surveillance program. Minimizing underreporting/under-participation is definitely a factor that needs to be considered when designing an occupational surveillance program. Appendix 6 contains an in-depth description of the 5 surveillance strategies.

Table 6. Surveillance strategies (Exposure Registry, Disease Registry, and Disease Screening/Medical Surveillance)

Surveillance Type	**Surveillance strategy**	**Definition**	**Strengths**	**Limitations**	**Example**	**Characteristics**	**Can be used for NMSC/ solar UVR?**
Exposure	Exposure Registry	Collects information about workers who have been exposed to a specific occupational risk or risks	-Allows for early identification of at-risk jobs or workers and disease -Allows for implementation of interventions that will prevent occupational injury and illness from occurring	-If voluntary results in **underreporting** -Generally only effective for specific high-hazard worksites or industries -If mandatory there is a need for legislation to be put in place	WorksafeBC exposure registry	-Since 2012 -British Columbia, Canada -Voluntary system -Exposures included: asbestos, formaldehyde, head lice, hepatitis, HIV, isocyanates, lead, meningitis, mercury, mould, noise, scabies, shingles, silica, thallium, tuberculosis, wood dust or other -Workers, employers, and others can record on-the-job exposures to harmful substances	Yes
Disease	Disease Registry	Collects information about workers who have been diagnosed with a specific disease	-Helps contribute to the secondary prevention of the disease -Helps to detect patterns of disease and this information can be used to prevent disease and reduce the health, economic and social costs	-Typically voluntary which results in **underreporting** -Exposure information collected retrospectively -Less useful for purposes of prevention -Limited by physician recognition of disease and willingness to participate (**under-participation)**	EPIDERM (Occupational skin surveillance)	-Since 1993 -Part of The Health and Occupation Reporting network (THOR) in UK -Voluntary reporting of occupational skin disease(including skin cancer) by 150 consultant dermatologists (20 core reporters report monthly and the remainder are sample reporters who are sampled at random and report for one month only each year) -Collects information about diagnosis, primary site of diagnosis, job title, industry, causal exposures (as reported by the physician), as well as date of first exposure	Yes
Disease	Disease screening/ medical surveillance	Monitors the occurrence of a specific disease or diseases within a defined population	-Program usually mandated by a regulatory body -Allows for early diagnosis and treatment of a specific OD -Reduces the chances of disease worsening or death	-**Under-participation** by workers in the actual screening (often due to fear of discrimination, job loss, that test results are not confidential, positive test results)	Coal Workers Health Surveillance Program (CWHSP)	-Since 1969 -NIOSH, USA -Mandatory to offer/voluntary to participate -To help prevent early coal workers' pneumoconiosis or black lung from progressing to a disabling disease	Yes

Note: Exposure registry ([19, 62, 63], Disease registry ([19, 64-67]), Disease screening [68-71])

Table 7. Surveillance strategies (Sentinel Event Surveillance, Disease Surveillance via Data Linkage)

Surveillance Type	Surveillance strategy	Definition	Strengths	Limitations	Example	Characteristics	Can be used for NMSC/ solar UVR
Disease	Sentinel Event Surveillance	Involves the ongoing/rapid identification of sentinel health events (defined as a preventable disease, disability, or untimely death that serves as a warning signal)	-Identifies emerging occupational hazards -Reduces exposure and eliminates risks	-Often mandatory to report OD, but not in practice. This results in **underreporting**	Norwegian Labor Inspectorate (NLI) Registry for Work-Related disease (RAS)	-Since 1977 -Norway -Mandatory for physicians to report all suspected and confirmed cases of work-related diseases to the Norwegian Labour Inspectorate (NLI) central registry -A physician reports a suspected or confirmed work-related disease to the NLI, the reported cases are evaluated by the NLI physicians, and the report is entered into an electronic database, the report is then sent to the regional NLI offices and they are responsible for deciding whether the case will be investigated further or an intervention put in place	Yes
Disease	Disease Surveillance via Data Linkage	Links various data sources to estimate the extent and distribution of occupational disease	-Provides reliable occupational information -Identifies at-risk groups of workers, and potential hazardous exposures, within the workplace -Contributes to understanding of occupational disease and can support changes to public health practice	-System only includes individuals who have actually submitted a workers compensation claim -Occupational information is only available at the time the claim is submitted	Occupational Disease Surveillance System (ODSS)	-Since 2016 -Ontario, Canada -Links existing provincial health databases with job information in order to study occupational disease and inform prevention activities -Data sources include: WSIB Time-Loss Claims Database, Registered Persons Database(RPDB), Ontario Cancer Registry(OCR), OHIP eClaims Database, National Ambulatory Care Reporting System(NACRS), Discharge Abstract Database(DAD)	Yes

Note: Sentinel Event Surveillance ([19, 72, 73], Disease surveillance via data linkage ([48, 62, 74, 75]

5.2 Results (2): Outcome of key informant interviews

Perspectives from selected Canadian and international jurisdictions

Interviews were conducted with 22 key informants in Canada (Alberta, British Columbia, Ontario, Saskatchewan, and Nova Scotia), Europe (the Netherlands, Norway, Italy, and Germany), the United Kingdom, Australia and the United States. As noted earlier in this report, participants were principally chosen on the basis of whether they had experience in designing or implementing occupational surveillance systems and/or expertise in skin cancer prevention/research.

The input received has been synthesized under the following three headings:

1. What are the perceived barriers to developing and implementing an effective occupational surveillance program?
2. What are the perceived facilitators to developing and implementing an effective occupational surveillance program?
3. What are the key considerations to developing and implementing an effective occupational surveillance program?

In Table 8 the top five barriers/challenges to developing and implementing an occupational surveillance system are presented. 59% of the key informants mentioned underreporting/under-participation as a key barrier and this corresponds with what is presented in the literature. All of these potential barriers need to be considered when designing an occupational surveillance program.

In Table 9 the top five facilitators in the development and implementation of an occupational surveillance system are presented. 64% of the key informants mentioned communication/collaboration at all levels as a key facilitator. This key component could promote buy in to a surveillance program and help to minimize underreporting/under-participation. Having all these potential facilitators in place would be beneficial when designing an occupational surveillance program.

Appendix 7 contains an in-depth description of the key informant interviews.

Table 8. Barriers to developing and implementing an occupational surveillance system

Barriers/challenges	Number of informants identifying this barrier	Significance
Underreporting/under-participation	13 (59%)	-Mentioned as a limitation in the literature as well -Makes it difficult to assess the true numbers of ODs -Due to long latency of ODs -Difficulty linking OD to work activities -Physicians do not have time to report -Physicians lack OD knowledge -Employee does not want disease recognized as work-related
Funding	11 (50%)	-Funding needs to be for the long term to sustain a proper surveillance program. -Often funding comes from research grants and there is no guarantee it will continue long term
Lack of awareness of risk	7 (32%)	-Employees/employers often do not understand the occupational risk they face -Employees/employers are less likely to participate in surveillance activities
Mandatory vs voluntary	5 (23%)	-Programs are often voluntary in nature and this results in underreporting/under-participation
Lack of a collection mechanism	5 (23%)	-Currently in Canada there is no collection mechanism for NMSC -NMSC is not included in cancer registries -Difficult to ascertain numbers of NMSC cases -Occupation information is also not collected (link between OD and work is difficult to make)

* Other barriers mentioned included: Cost of preventive measures, Lack of an OEL for sun exposure, NMSC not recognized as an OD

Table 9: Facilitators in the development and implementation of an occupational surveillance system

Facilitators	Number of informants identifying this facilitator	Significance
Communication/ collaboration	14 (64%)	-Critical to have all stakeholders at the table as this facilitates buy in to the program -Allows for better understanding of what is going to happen and why information is being collected -Can be accomplished via Outreach/education at worksite -Direct contact (relationship building) with employers and workers allows for buy in and means they are more likely to participate in surveillance
Simple reporting process	5 (23%)	-Will allow for buy in particularly from physicians -Reporters do not want to spend a lot of time reporting -Can combat underreporting
Long term funding	5 (23%)	-Surveillance is a long term proposition -Guaranteed funding will allow for a strong program that will be impactful
Strong team/leadership	4 (18%)	-Will make the surveillance system manageable and successful in the long run
Physician related factors	4 (18%)	-Better education of physicians so that they can recognize OD and report it -Educating physicians about the usefulness of surveillance and how it helps workers -Have physicians collect occupation information so that there is a record of occupation

* Other facilitators mentioned included: Legislation, Strong scientific evidence, Incentives, Clear goal

5.3 Discussion

We did not find any occupational surveillance systems in the grey or published literature that focused directly on outdoor workers. However, we were able to collect and summarize a wide variety of surveillance programs that have been created for workers exposed to many different occupational hazards and subsequently at risk of a broad range of negative health outcomes.

The most important barriers to an effective surveillance system identified by our key informants included underreporting and under-participation (59% of key informants mentioned this barrier), funding (50% mentioned) and a lack of awareness of the risk (32% mentioned). Surveillance systems depend upon completeness (or near completeness) in order to be effective, so it is not surprising that the key informants identified this barrier. If underreporting occurs, the surveillance system may become biased, since proactive and better funded employers might be more likely to participate, for example. Funding is always a challenge in data collection and research, and is a particular challenge for surveillance because it is *by definition* ongoing; it cannot be wrapped up as a grant project in 2 or 4 years. The lack of awareness of risk is an interesting barrier; for diseases with long latencies (like skin cancer), this can be a particular challenge.

The most important facilitators for an effective surveillance system identified by our key informants included communication and collaboration (64% of key informants mentioned this facilitator), having a simple reporting process (23% mentioned) and long-term funding (23% mentioned). The purpose and importance of a proposed surveillance system should be understood by all parties who are required to ensure its success and this can only be achieved by open communication and a spirit of collaboration. Obtaining buy-in from key parties ahead of time will help to ensure the long-term success of a surveillance system. Having a simple reporting process is a key facilitator as it works to address some of the barriers (e.g. underreporting), and will especially be important in cases where physicians or other front-line health care workers are required to be a part of reporting. Funding was identified as a facilitator much as lack of funding was identified as a key barrier.

Key considerations in the design of an occupational surveillance program

During the telephone interviews the participants were asked some specific questions regarding their involvement in the design and implementation of an occupational surveillance program (Appendix 7). The answers provided highlight some key considerations that should be included in the design phase of an occupational surveillance program for outdoor workers in Alberta.

1) Have a clear purpose/goal
    - The question that is trying to be answered or the problem that is trying to be solved or measured needs to be clear.
2) Have a defined target population
    - Who or what population the surveillance program is focused on needs to be apparent. Is it all workers or a subgroup like outdoor workers?
3) Have stakeholder involvement
    - Which stakeholders need to be involved during the design and implementation of a surveillance program needs to be determined from the beginning. Having these stakeholders involved throughout the various phases of the program is important.
    - Important groups to consider (which may or may not be applicable depending on the answers to 1) and 2) above) are occupational physicians, OHS professionals, labour representatives, academics/scientists, data managers, employers, and

regulators.

4) Exposure vs disease monitoring
    - Whether the focus of the surveillance program is on exposure or disease (or both) needs to be clear.
    - A good first step that came out of our interviews would be to focus on ascertaining the numbers of outdoor workers affected by NMSC (disease monitoring).
5) Assess resources available
    - The available resources will determine the eventual robustness of the system being designed.
    - It is important to have funding available for a minimum of 10 years to enable development of a strong system.
6) Assess available data sources/how to capture data/how to analyze
    - How data will be collected needs to be clearly planned. Will existing data sources be used or will a new data capture process be implemented? How will the data be analyzed? How will it be stored long term and how can data security be maintained?
    - The first step would be assessing data holdings that would allow ascertainment of the numbers of NMSC occurring in outdoor workers. This could be done via physician billing data, via physician reporting, via a cancer registry (if data was tabulated there or could be going forward), or workers compensation data (perhaps less useful if workers are not making claims for NMSC cases).
7) Ensure that there is a pilot phase
    - A pilot phase will help determine how the system works, will identify any flaws, bugs or areas of concern.
    - It is important to continuously monitor and improve the system as inefficiencies are discovered or as new technologies become available. This will help to prevent the system from becoming obsolete over time.
8) Evaluate the program
    - Evaluation is a critical step to ensure that the program is working as designed and to determine what the data is telling us.
9) Disseminate results
    - Dissemination is another critical step to share results and learnings, and can inform the development of new and improved prevention programs, interventions, or policies.
10) Develop interventions, prevention programs, guide policy, continue to educate
    - The vitality of a surveillance system will depend upon how useful it is. It should be used to develop new products or programs that will help to reduce the occupational hazards experienced by outdoor workers and ultimately reduce the risk of NMSC (and perhaps other negative health outcomes).

Key recommendations for a NMSC surveillance program

The five consulted surveillance strategies (exposure registry, disease registry, disease screening/medical surveillance, sentinel event surveillance and disease surveillance via data linkage) could all likely be used for the surveillance of NMSC or sun exposure, however, there are strengths and limitations to all approaches. It is truly difficult to assess exactly how successful the individual strategy will be for NMSC/sun exposure since they have not been used specifically for NMSC/sun exposure. During the literature review and the key informant interviews one country does stand out above the rest when it comes to the surveillance of NMSC/sun exposure. Germany is the most advanced in their surveillance of and recognition of NMSC as an OD and therefore can potentially be used as a model.

The system in Germany includes a mechanism to keep track of the incidences of NMSC in outdoor workers, includes a medical screening component for outdoor workers and integrates primary prevention strategies and education into their program. Since 2015 NMSC (including squamous cell carcinoma and multiple actinic keratoses) is recognized as an OD and notified to the Deutsche Gesetzliche Unfallsversicherung (DGUV) or German Social Accident Insurance [76]. After the first 12 months of official recognition, more than 7,700 occupational NMSC cases were registered with the DGUV [53]. In 2018, the number of notifications was over 9, 000 and it is expected that these numbers will continue to increase. In Germany, physicians are offered a financial incentive which helps to encourage physicians to report [53]. Patients who have been diagnosed with occupational skin cancer are provided priority medical care and, in severe cases, substantial compensation [53]. Since July 2019, Germany includes a medical screening program as part of their surveillance of outdoor workers. Employers have been mandated by the government to offer skin screening every three years to workers who work outside for more than 1 hour per day for 50 days per year. It is not compulsory for the employee to take part in the screening, but it is mandatory that the employer offers it. Employers must also offer protection measures to their workers if the workers are exposed to solar UVR (German dermatologist, personal communication, November 4, 2019).

Based on some of the work done in Germany we propose some steps that would help drive the design and implementation of a surveillance program that focuses on NMSC/sun exposure forward. These steps can be implemented over a number of years.

1. Recognize NMSC due to solar UVR as an occupational disease

    - Currently Germany recognizes multiple Actinic Keratosis (AK) and Squamous Cell Carcinoma (SCC) as ODs [76]. They have strong scientific evidence to link AK and SCC to solar UVR exposure during work [77]. They are currently working on research linking Basal Cell Carcinoma (BCC) to work related solar UVR exposure [78], but this is also now a scientifically accepted link and so BCC should be included in any system going forward.

2. Create a notification/collection mechanism for NMSC

    - Germany has a notification system in which physicians report occupational NMSC to the DGUV. In this way, they are able to keep track of incidence. Another possible way to do this could be via a cancer registry or physician billing data. It is important to include occupational information here.
    - For Canada, steps should be taken at the provincial level to improve notifications of skin cancers through both occupational services and public health programs [54].
    - Most provinces do not centralize the data on NMSC in any central repository, and it presumably lives primarily in physician billing data. Efforts should be taken to create systems to be able to count NMSCs over time.

3. Continue/build on/improve primary prevention initiatives

    - Canada has created some strong primary skin cancer prevention programs for outdoor workers including Sun Safety at Work Canada (https://sunsafetyatwork.ca/) and Be Sunsible from Alberta (https://besunsible.healthiertogether.ca/). These need to be easily accessible to employers and employees, and maintained and updated as needed going forward.

4. Educate workers and employers on the risks of solar UVR

    - "Take steps to increase knowledge about the risk of AK and NMSC among occupational workers to empower and change behaviour among these groups, and ensure proper follow-up to detect and treat appropriately with the latest efficacious medicines available" [54].
    - "The development of smart, simple and accessible information platforms is warranted beyond leaflets and information campaigns, e.g. through social media, to improve health literacy among outdoor workers and the general population to drive change in behavior" [54].

5. Introduce a medical screening component

    - Employers can be encouraged to offer occupational skin cancer screening programs among the at-risk workforce
    - Employers can measure the levels of workers' exposure to UVR and to implement plans to prevent exposure exceeding the limit values
    - Eventually a mandate may be warranted to encourage employers to comply

Knowledge translation completed and in progress

We have created several knowledge products in relation to this sub-study, and have some more work planned that will continue post-project.

1. Webinar
    - We advertised and hosted a webinar on February 27, 2020 to share the results of both the measurements and the monitoring sub-study. Approximately 80 people attended the webinar, which had a lively Q&A period. A post-webinar survey was sent out which was filled out by 14 participants (a copy of the survey results is included in Appendix 3).
2. Scientific paper in preparation
    - We are drafting a paper containing the results of this sub-study to submit to the journal *Safety and Health at Work*. We expect to submit the paper by September 2020. The paper is titled "Sun exposure in outdoor workers: key considerations for an occupational surveillance system" and was authored by Nicole Slot, Lindsay Forsman-Phillips, Victoria Arrandale, Sunil Kalia, D. Linn Holness, Thomas Tenkate, and Cheryl Peters.
3. Abstract to be submitted: Canadian Association for Research on Work and Health (conference tentatively planned for June 2021 in St. John's Newfoundland)
    - This conference is scheduled to occur next June, and it appears it will be a virtual conference if an in-person meeting is not possible. We intend to present the results of this sub-study in either scenario.
4. Web presence: CAREX Canada website and Sun Safety at Work Canada
    - As soon as results are completely final (i.e. two primary results papers have gone through peer review), we will update the current project page (https://www.carexcanada.ca/special-topics/sun-safety/) as well as create a study page on the Sun Safety at Work Canada website (https://sunsafetyatwork.ca/). We are currently working with partners to develop visually-appealing content for this purpose. We anticipate this will go live in fall 2020.

Section 6: Overall conclusions

Our study demonstrated that sun exposure is a clear occupational hazard for outdoor workers in Alberta, and that there are few examples worldwide of jurisdictions who have surveillance systems in place to support the exposure and NMSC risk reduction in this vulnerable worker population. Programs have been developed in Canada over the years to help support employers in controlling exposure to solar UVR among their workers, but evaluation of these programs has been limited to date. This speaks very much to our finding from this study that sustained funding, data infrastructure, and clear communication and collaboration are vital to the tackling of occupational skin cancer prevention as well as the undertaking of occupational surveillance more broadly. Some key conclusions from each sub-study are as follows:

For the UVR exposure sub-study:

Outdoor work places workers at considerable risk of solar UVR exposure over the international recommended exposure limit guideline in the summer months in Alberta. Almost half of the workers were exposed to levels that exceeded the international occupational exposure limit guideline. Exposure was highest among landscape and maintenance services, as well as trade and recreational workers, on mixed days, and when the dosimeters were placed on workers' hardhats. These findings will help inform future exposure monitoring studies in Alberta and elsewhere in Canada, as well as prevention initiatives that aim to reduce skin cancer risk among outdoor workers.

For the monitoring sub-study

Outdoor workers are exposed to numerous workplace hazards. Solar UVR is a substantial risk factor for outdoor workers and has often been underestimated if not neglected completely as an occupational risk. Due to high exposure that we demonstrated in the UVR exposure sub-study, we know that it is important that outdoor workers be monitored or surveilled to ensure that proper primary prevention strategies are in place to minimize the risk of developing NMSC, to ensure that disease is caught at an early stage and to ensure that incidences of NMSC in outdoor workers are tracked. This can be achieved via an occupational surveillance program that focuses on outdoor workers and NMSC. It should be additionally considered to include a variety of exposures of interest in such a surveillance system, or a broader group of health outcomes. These exposures may include other chemical exposures, pesticides (especially where co-exposure with the sun increases the risk of skin cancer), coal tar pitch, silica dust, and diesel engine exhaust (as pertinent to the industry). The health outcomes in addition to solar UVR could include other skin conditions, eye conditions, lung cancer, and hematopoietic cancers, for example.

Relevance to Alberta workers, workplaces, employers, and decision makers

The results of our study demonstrate a clear gap in our understanding of how outdoor workers are impacted by their solar UVR exposure. We found that exposure levels were both consistently too high and also varied dramatically, both within and between workers. This shows that more sampling for solar UVR needs to happen in Alberta workplaces, especially given that the summer of 2019 (when sampling occurred) was a relatively cloudy and rainy summer – other more typically sunny Alberta summers would inevitably lead to exposure levels that are even higher than what we found. This is of key interest to workers and workplaces in Alberta who could be the target audience for educational campaigns to understand the risk that their high sun exposure poses to them and their future health. It is also of key interest for employers; tools exist to support employers in helping to control solar UVR exposure among their workers. On the level of decision-makers, there are a few key takeaways: 1) exposure to the sun is occurring at levels that are likely increasing the risk of skin cancer in outdoor workers in Alberta; 2) there is no surveillance of exposure to the sun nor the occurrence of skin cancer among Alberta's outdoor workers; and 3) there are a variety of tools available to reduce workers' exposure to the sun, and/or to set up a surveillance system to monitor their exposures and/or health outcomes in the long term.

Recommendations for future research

1. Additional UVR sampling campaigns should be undertaken in subsequent summers in Alberta as well as in different areas in Canada and among different groups of workers in order to gain a more fulsome understanding of the levels of exposure experienced across more work settings, and also to characterize the variability experienced both within and between workers. If we add to the growing database of solar UVR measurements, we could more accurately characterize exposure by job title and use this information to infer exposure in situations where measurements are not feasible.

2. Systems should be designed and created to better track incident NMSC in Alberta and elsewhere in Canada. Currently, we only have an *estimate* of the yearly incidence of NMSC in Canada because most provinces do not routinely amalgamate this information from billing data and other sources that may exist. If we are to tackle the issue of occupational skin cancer prevention, we require solid data in order to benchmark our health outcomes to evaluate our programs in the future.

3. Outdoor work carries with it a somewhat unique set of challenges, and we found that exposures occurring in outdoor workers have not typically been considered together. We would recommend that future research address the issue of other occupational health hazards experienced by outdoor workers, including solar UVR exposure, but expanding into other co-exposures experienced by this group.

Section 7 Appendices

7.1 Appendix 1: Questionnaire used in UV radiation exposure monitoring piece

Date: ☐☐/☐☐/☐☐☐☐ FOR RESEARCHER USE ONLY

Day Month Year Dosimeter ID / Sample #:__________ Location ID:________

Alberta Outdoor Workers Project Questionnaire

This questionnaire has 4 sections. In **Section 1**, we will gather information on your sun habits, both when you are at work and on your leisure time. **Section 2** asks questions about personal characteristics that may be associated with skin cancer risk, such as skin and hair colour. **Section 3** will gather information on your job, and **Section 4** asks some demographic questions. All information provided to us is confidential and will not be released to another party without permission. If there are any questions that you are not comfortable answering, you do not have to answer them.

For each question listed, please select the **one answer** that is the best response to the question. Fill in each circle or mark with a tick. ✓ Return completed surveys to **Brandon Leong (403.476.2490), or email them to me at Brandon.leong@ahs.ca**). You can also speak to Brandon on site if you need clarification on any of the questions.

Section 1: Sun Habits

1. In the summer, on average, how many hours are you outside per day between 10 AM and 4 PM., on days <u>when you are AT WORK?</u>

1 hour or less…………………………………………………O
2 hours……………………………………………………………O
3 hours ……………………………………………………………O
4 hours……………………………………………………………O
5 hours……………………………………………………………O
6 hours……………………………………………………………O

2. In the summer, on average, how many hours are you outside per day between 10 AM and 4 PM.. on days <u>when you are NOT AT WORK?</u>

1 hour or less…………………………………………………O
2 hours……………………………………………………………O
3 hours ……………………………………………………………O
4 hours……………………………………………………………O
5 hours……………………………………………………………O
6 hours……………………………………………………………O

3. How often do you spend time <u>in the sun</u> in order to get a tan?

NEVER	RARELY	SOMETIMES	OFTEN	ALWAYS
O	O	O	O	O

4. How many times LAST SUMMER did you have a red OR painful sunburn that lasted a day or more? (Circle one response)

0	1	2	3	4	5+

For the following questions, think about what you do when you are outside <u>AT WORK during the summer on a warm sunny day.</u>

	NEVER	RARELY	SOMETIMES	OFTEN	ALWAYS
5. How often do you wear SUNSCREEN?	O	O	O	O	O
6. How often do you wear a SHIRT WITH SLEEVES that cover your shoulders?	O	O	O	O	O
7. How often do you wear a HAT?	O	O	O	O	O
8. How often do you stay in the SHADE or UNDER AN UMBRELLA?	O	O	O	O	O
9. How often do you wear SUNGLASSES?	O	O	O	O	O

For the following questions, think about what you do when you are outside <u>and NOT AT WORK during the summer on a warm sunny day.</u>

	NEVER	RARELY	SOMETIMES	OFTEN	ALWAYS
10. How often do you wear SUNSCREEN?	O	O	O	O	O
11. How often do you wear a SHIRT WITH SLEEVES that cover your shoulders?	O	O	O	O	O
12. How often do you wear a HAT?	O	O	O	O	O
13. How often do you stay in the SHADE or UNDER AN UMBRELLA?	O	O	O	O	O
14. How often do you wear SUNGLASSES?	O	O	O	O	O

Section 2: Personal characteristics

15. What is your natural hair colour? If grey, what colour was it before it turned grey?

Red or light blonde	Blonde	Dark blonde or light brown	Dark brown	Black
O	O	O	O	O

16. What are the colour of your eyes?

Light blue, light grey, or light green	Blue, grey, or green	Hazel or light brown	Dark brown	Brownish black
O	O	O	O	O

17. Which of the following skin colours best characterize you?:

Skin colour is **light, pale white** (*Always burns, never tans*)………………………………………..O
Skin colour is **fair** (*Usually burns, tans with difficulty*) ……………………………………………….O
Skin colour is **white to olive** (*Sometimes develops a mild burn, gradually tan*) ……………O
Skin colour is **olive to moderate brown** (*Rarely burns, tans with ease*) ………………………O
Skin colour is **brown to dark brown** (*Very rarely burns, tans very easily*).. …………………………O
Skin colour is **very dark brown to black** (*Never burns, tans very easily*)………………………O

18. As a child, did you have more than one severe sunburn? (i.e. painful and/or blistering)

O No O Yes

19. Have you ever been told by your doctor that you have skin cancer?

O No O Yes O Don't know If **YES**, what type? (e.g. melanoma, squamous cell, basal cell carcinoma. Leave blank if unknown.)

____

20. Has anyone in your IMMEDIATE family (mother, father, sister, brother, child) been told by a doctor that they have skin cancer?

O No O Yes O Don't know If **YES**, what type? (e.g. melanoma, squamous cell, basal cell carcinoma. Leave blank if unknown.)

____

21. Do you have a skin condition that worsens with sunlight exposure?

O No O Yes O Don't know If YES, what type (e.g. photosensitivity, 'allergy')?

____

22. Have you ever worked with creosote before?

O No O Yes O Don't know If YES, for approximately how many years?

____

Section 3: Job information

23. What is your CURRENT job title or trade?

____

24. What are your main job tasks? (for example "welding" or "operating an excavator")

____

____

____

25. How long have you been working in your CURRENT job or trade?

__________________ years

26. Would you describe your typical CURRENT job/trade schedule as:

<30 hours/week	30-40 hours/week	40-50 hours/week	>50 hours/week
O	O	O	O

27. Is your current job the job or trade you have held the longest?

O No O Yes (If **YES**, then skip to question 29 in SECTION 4)

28. **If you answered NO to question #27, what has been your USUAL occupation or job -- the one you have worked at the longest?**

Job title ____

Number of years employed in this LONGEST (or usual) occupation _______________

Main job tasks at your LONGEST job (i.e. waiting tables, installing cabinets, pouring concrete)

____

____

____

# of hours in SUMMER spent outside between 10am and 4pm at your LONGEST job:_________

Section 4: Background Information

29. Your sex:

O Male O Female

30. Date of birth: ☐☐ / ☐☐ / ☐☐☐☐

Day Month Year

31. Racial/ethnic background: (Fill in one best choice)

O Caucasian/White O Asian

O Black O Other ____________________

O Hispanic

32. What is the highest certificate, diploma or degree that you have completed?

O Less than high school diploma or its equivalent (i.e. GED)

O High school diploma or its equivalent

O Some college, trade school, or university

O Completed college, trade school or university degree

33. Your name: ____

34. Your email (optional, if you would like a copy of your results): __________________________________

You have reached the end of the questionnaire.
Please be sure to return your complete questionnaire to Brandon (403.650.8881) or email him at Brandon.Leong@ahs.ca

Thank you very much for participating!

7.2 Appendix 2: Worked example from UVR exposure model

Models were performed on log-transformed data; consequently, the results must be exponentiated to obtain interpretable estimates. For an example of how to transform the model findings into estimates, consider equation (4).

(4)

$$
\begin{aligned}
\text{ln-SED}_{day} = \; & 0.261\,(\textit{hours outside}) \\
& + \beta_2\,(\textit{education}) \\
& + \beta_3\,(\textit{hair colour}) \\
& + \beta_4\,(\textit{trade}) \\
& + \beta_5\,(\textit{city/region}) \\
& + \beta_6\,(\textit{dosimeter placement}) \\
& + \beta_7\,(\textit{forecast}) \\
& - 1.29
\end{aligned}
$$

Hypothetically, if a trade worker in Edmonton mounted the dosimeter on their hardhat, had a high school education, had red hair, and worked for 5 hours on a sunny day, then:

ln-SED_{day} =

0.26 (hours outside) +
+ [0.29 (high school or less=1) - 0.14 (some college=0) + 0 (completed college=0)]
+ [-0.07 (dark brown/black=0) + 0.33 (red/blonde=1) + 0 (dark blonde/light brown=0)
+ [-0.03 (landscape/maintenance services=0) - 0.54 (professional services=0)
0.18 (recreational worker=0) - 0.97 (security worker=0) + 0 (trade worker=1)]
+ [0.12 (Edmonton=1) + 0.65 (other=0) + 0 (Calgary=0)]
+ [0.47 (hardhat=1) + 0 (lapel/watch)]
+ [-0.747 (cloudy=0) + 0.027 (mixed=0) + 0 (sunny=1)
- 1.29

$$
\begin{aligned}
\text{ln-SED}_{day} = \; & 0.26\,(5) + \\
& + 0.29\,(\text{high school}=1) \\
& + 0.33\,(\text{red hair}=1) \\
& + 0\,(\text{trade worker}=1) \\
& + 0.12\,(\text{Edmonton}=1) \\
& + 0.47\,(\text{hardhat}=1) \\
& + 0\,(\text{sunny}=1) \\
& - 1.29 \\
= \; & 1.3 + 0.29 + 0.33 + 0 + 0.12 + 0.47 + 0 - 1.29 \\
= \; & 1.22
\end{aligned}
$$

$$
\begin{aligned}
\text{SED}_{day} &= \exp(1.22) \\
&= 3.39 \text{ SED}
\end{aligned}
$$

This hypothetical trade worker would expect to receive 3.39 SED, given the stipulated conditions on this hypothetical day.

The general relationship between the variable and SED values can be assessed using the sign of the beta values. For example, a negative beta coefficient means that the variable will contribute to lower SED values. Statistically speaking, being a security worker and working on cloudy day may lead to lower SED measurements compared to trade workers and sunny days, respectively, while a larger number of hours worked outdoors contributes to higher SED values.

7.3 Appendix 3: Post-webinar survey results

Please refer to the PDF “Post-Webinar survey results.” It has been submitted separately.

7.4 Appendix 4: Table of surveillance practices

Please refer to the PDF “Table of surveillance practices”. It has been submitted separately.

7.5 Appendix 5: Interview questions/questionnaire

Sun exposure in outdoor workers – Key informant interviews

We will interview approximately 20-25 key informants from government agencies, worker advocacy groups, non-government organizations, and Canadian or international researchers with expertise in occupational health and skin cancer prevention.
The interviews will focus on the following domains:

- Verification that our scan of best practices for occupational exposure/health surveillance is complete and that key inputs have not been missed
- Best practices for design and implementation of a surveillance system for outdoor workers
- Barriers and facilitators to creating, managing, and ensuring the ongoing success of an occupational surveillance system for outdoor workers

Questions will include:

Key informant information

1. Do you consent to participating in this interview on surveillance systems for outdoor workers? Do you consent to an audio recording of this interview for transcription and data analysis purposes?
2. What organization do you work with and what is your jurisdiction?
3. What is your primary role?
4. How does your work relate to skin cancer prevention and/or occupational health of outdoor workers?
    a. What work have you done in this area?

Design and Implementation of a surveillance program

5. Have you been involved in designing or implementing an occupational exposure or health surveillance program?
    a. If yes what were the motivations behind developing the surveillance program?
    b. Who was involved in the development of the surveillance program (i.e. government, multi sectoral, research)?
    c. What exposures are included in the surveillance program? How was the exposure or exposures assessed and added to the surveillance program?
    d. Is there policy developed that supports or requires the surveillance program?
    e. How was the surveillance program implemented and designed, (i.e. what steps were taken in the development and implementation of the program)?
    f. Is sun exposure included in the surveillance program?

g. What data sources were used to develop, and maintain the surveillance program (voluntary, insurance, enforcement, health)?
h. What tools are used to evaluate the effectiveness of the surveillance program?
i. How are the results disseminated or circulated?

Barriers and facilitators

6. Based on your experiences, what are some of the barriers or challenges to developing and implementing an effective (sun exposure/skin cancer) surveillance program (for outdoor workers specifically)? Do you have any thoughts on how these can be overcome?
7. What are the facilitators or what would support the development or implementation of a successful (sun exposure/skin cancer) surveillance program (for outdoor workers)?
8. Do you have any lessons learned from your experience with developing or implementing a (sun exposure/skin cancer) surveillance program (for outdoor workers) that you could share with us?

Best practices for an occupational exposure/health surveillance program

9. Please refer to the results of our environmental scan of best practices for designing and implementing an occupational exposure/health surveillance program. Are there any other examples of best practices that could be included here?
10. Is our appraisal of the individual practices accurate? a. Are you aware of any additional evidence to indicate which of these approaches should be deemed best practice?

Summary/end of interview

11. Can you suggest anyone else with whom we should speak to as part of this research project?
12. Can I contact you again if I need to clarify anything in this interview?

Thank you for your time

7.6 Appendix 6: Surveillance strategies

Five surveillance strategies are described below. These particular strategies appear most often in the Table of Surveillance Practices and they have potential to be applied to a system for outdoor workers.

Exposure Registry:

The Table of Surveillance Practices includes 16 articles or reports that focus on the use of an exposure registry for occupational surveillance [18, 19, 79-92]. Exposure registries are designed to collect information about workers exposed to a specific occupational risk or risks and can be used to assist in compensation related decisions, as a reason for disease screening, to carry out exposure surveillance, or to help identify new exposure-disease relationships [19]. An exposure registry enrolls workers into a system that collects various types of information including demographic, employment, and exposure information. The goals of an exposure registry can differ depending on the reason it was created in the first place: an exposure registry can gather information about the exposure history of an individual worker for purposes of future decision making about compensation; the information on an individual worker's exposure history can be used to administer a disease screening program for individual workers; the information can be used for exposure surveillance in a population of workers with the goal of reducing exposures and preventing the development of diseases; or the information on exposure in a population of workers can be used as a basis for health surveillance with the goal of identifying new exposure-disease relationships [19]. The information collected in an exposure registry may give the opportunity for primary prevention through the elimination or reduction of the exposure and it can also be used for secondary prevention via disease screening of high exposure groups [19].

Since 2012 WorkSafeBC implemented an online exposure registry program. Workers, employers, and others have been able to enroll and permanently record on-the-job exposures to harmful substances. The main exposures included are asbestos, formaldehyde, head lice, hepatitis, HIV, isocyanates, lead, meningitis, mercury, mould, noise, scabies, shingles, silica, thallium, tuberculosis, wood dust or other (WorkSafeBC, personal communication, October 16, 2019). Since many occupational diseases develop after a prolonged exposure or after a long latency period the information in the registry can be useful for a future diagnosis, as proof for a work related cause of disease, and for claims decisions. The registry can be helpful to guide prevention efforts by providing data that can be used to monitor industry trends and raise the awareness on how harmful exposures can be linked to occupational disease [63]. In the past year WorkSafeBC has had about 700 submissions to the registry and this continues to increase as workers and employers become more aware of the registry and how to use it (WorkSafeBC, personal communication, October 16, 2019).

An exposure registry may be a strategy to monitor outdoor workers and their exposures. It could be designed to keep track of the exposure history of an outdoor worker. For example if a worker spends most of the workday outdoors and is exposed to prolonged solar UVR this could be registered for purposes of future compensation claims or for a future diagnosis. If an exposure limit for solar UVR is defined and a worker exceeds this limit a disease screening program could be administered to diagnose solar related disease at an early stage. As with the WorkSafeBC registry the employee or employer could register exposures that are not only limited to solar UVR, but could include excessive heat or cold, respiratory exposures, exposure to infectious agents, exposure to parasites (i.e. ticks). A central registry can be set up to keep track of the submissions. This can be done via a simple online form for registration. It is also possible that the employer sets up a registry for employees if they are exposed to specific risks on the job. At the end of the year the employer could submit this information to a central registry. If it is determined that certain groups have high exposure to certain risks for example solar UVR, disease screening could be implemented to ensure that there are no early signs of skin cancer. In BC it did not take very long to create their exposure registry and this registry could be used as an example for Alberta. An exposure registry can include numerous exposures not only those experienced by outdoor workers, so it has the potential to be extended to all workers and exposures.

Disease Registry:

The Table of Surveillance Practices includes 17 articles or reports that discuss the use of occupational disease registries for surveillance [20, 58, 64, 67, 88, 93-104]. Disease registries are similar to exposure registries, but only include workers who have been diagnosed with a specific disease (for example skin cancer, dermatitis or mesothelioma). Most often registrations are done on a voluntary basis and by physicians. Because of the voluntary nature of this type of registry there can be substantial underreporting of the disease and this is certainly a limitation to this method of surveillance [67]. The disease registry can be designed to also collect exposure information, however, this is typically done after the fact and could cause a recall bias [19]. Disease registries are quite common in Europe, though they have been used in Australia (e.g. SABRE for respiratory disease) [98, 101] as well. Canada has done some studies looking into this method [102, 103]. One study focused on the Ontario Work Related Asthma Surveillance System (OWRAS) and the other on a physician based surveillance system of occupational respiratory diseases (PROPULSE) in Quebec. Both studies determined that it is feasible to implement a voluntary reporting system, but physician participation is often low and this method should be used as a supplement to other data sources [102] or with other surveillance methods.

The UK's Occupational Skin Surveillance (EPIDERM) is an example of a disease-based registry [65]. EPIDERM is part of The Health and Occupation Reporting network (THOR) in the UK and it has been in place since 1993. In EPIDERM consultant dermatologists voluntarily report cases of occupational skin disease to a central unit that compiles the data and undertakes analysis. Information about diagnosis, primary site of diagnosis, job title, industry, causal exposures (as reported by the physician), as well as date of first exposure is collected by the Centre for Occupational and Environmental Health in Manchester (COEH, personal communication, September 26, 2019). Currently about 150 consultant dermatologists report to EPIDERM. There are about 20 core reporters who report every month to the registry and the rest of the dermatologists are sample reporters who are sampled at random and report for one month only each year (COEH, personal communication, September 26, 2019). The major category of cases reported consists of contact dermatitis, followed by neoplasia (cancers) [65].

A downside of EPIDERM or disease registries are their voluntary nature and the underreporting that often occurs as a result. It is difficult to know exactly how many cases are being missed and how representative the captured cases are of the larger population [19]. Underreporting is likely to be an issue for THOR [20], and some factors that contribute to underreporting include under-recognition (i.e. the condition/disease is not linked to work), under-participation by physicians due to workload, the physician's level of training in occupational diseases [64] and perhaps the employee not wanting the work related nature of the disease recognized [67]. Disease-based registries are limited in their ability to address trends through surveillance or epidemiology if a large portion of the population is missing from the registry. "Disease registries are also less useful for purposes of prevention than exposure registries since workers will already have developed the disease before they register. Disease registries can, however, help contribute to the secondary prevention of those diseases for which medical strategies exist that can slow or even reverse the progression" [19].

A disease registry could be used for outdoor workers in that it could collect information about specific occupational diseases that this group of workers are diagnosed with. Though if this method were used, it would likely have to focus on one type of disease as opposed to all the possible occupational diseases that an outdoor worker may be diagnosed with. A similar system to EPIDERM could be developed in which dermatologists report incidences of occupational NMSC to a registry. This may be a way to ascertain the actual numbers of occupational NMSC, however, it may be difficult to get already busy dermatologists on board to do this type of reporting. Therefore, there could be substantial underreporting as with EPIDERM and this may be difficult to overcome. One way to perhaps minimize the underreporting is to put some sort of legislation in place so that physicians are more likely to report, however, this may not solve the problem as some countries do have legislation in place and underreporting still exists. Another way to minimize underreporting is to offer physicians incentives to report. This has been a successful approach in Germany.

Disease screening/medical surveillance:

The Table of Surveillance Practices includes 6 articles or reports that discuss the use of disease screening/medical surveillance as a strategy for surveillance [69, 71, 105-108]. Disease screening or medical surveillance monitors the occurrence of a specific disease or diseases within a defined population. Typically disease screening is mandated by a regulatory body. The screening is conducted to determine whether a worker has had excessive exposure to a specific agent [68] and whether there are early signs of work related disease [71]. The screening allows for the possibility of early diagnosis and treatment and ultimately reduces the chances of the disease worsening or that a worker dies from the disease [68]. These tests are normally administered to workers who are considered healthy [71]. This type of screening is really only effective for diseases for which early detection is beneficial. A medical surveillance program on the other hand takes place over a longer period of time with recurrent examinations and data analysis [71] and includes a wider range of activities [68].

An example of a medical surveillance system is the Coal Workers' Health Surveillance Program (CWHSP) of the U. S. National Institute of Occupational Safety and Health (NIOSH). In 1969 the CWHSP was established by the Federal Coal Mine Health and Safety Act of 1969 to prevent early coal workers' pneumoconiosis or black lung from progressing to a disabling disease. This act as well as the Mine Safety and Health Administration (MSHA) rule for respirable coal mine dust require that periodic chest x-rays, periodic lung function testing (called spirometry), respiratory health assessment questionnaires, and extended health surveillance are offered to surface, underground, and contract coal miners [70]. The Coal Mine Health and Safety Act mandates that NIOSH and the MSHA operate the CWHSP, therefore it is mandatory for the program to be offered but it is voluntary for the miners to participate. "The first X-ray upon entry into the coal mining industry is mandatory. And then depending upon that result, another two x-rays may be mandatory within the first five years but beyond that, it is all voluntary"(CWHSP, personal communication, December 4, 2019). The disease screening component of the program includes a chest x-ray for all underground coal miners and since 2014 all surface coal miners, as well since 2014 includes spirometry testing and a respiratory assessment for all coal miners [109]. As part of this program, new coal miners must be offered by their employer chest x-rays as well as spirometry testing and a respiratory assessment at specific times: (1) within 30 days of commencement of employment in an underground or surface coal mine, (2) three years following the initial x-ray/spirometry/respiratory assessment and if the worker is still working in a coal mine; (3) two years following the second x-ray/spirometry/respiratory assessment, if the second examination showed any evidence of pneumoconiosis and if the worker is still working in a coal mine; and, (4) every five years thereafter [109]. NIOSH notifies the miners of the results and if anything abnormal is found, the coal miner will be advised to follow up with their physician or contact one of the government-supported Black Lung Clinics [109]. The results of these tests are collected and analyzed by NIOSH and it allows researchers to identify trends in disease progression across the nation [110]. This program is voluntary and this is a drawback [19]. "In a given year it's about/it fluctuates between 25 and 40% of the industry is participating when they're eligible. Right now it's about 35%. And it's very region dependent. So out west we have really high participation in some of the states, you know, upwards of 50 to 70%. And in central Appalachia, the percentages are below 20" (CWHSP, personal communication, December 4, 2019). The reasons for the under-participation include fear of discrimination, fear of job loss, the screenings are not easily accessible/scheduling issues, fear that confidential test results will be shared with the employer, fear of finding out they are ill. To combat the under-participation in the program it has been suggested that all screening become mandatory. Also the Enhanced Coal Workers Health Surveillance Program (ECWHSP) has been implemented to try to help increase participation. The ECWHSP uses a mobile testing unit and it travels to convenient locations to offer the screening tests to both current and past coal miners [110].

Medical screening/surveillance could be used for outdoor workers particularly if the workers are regularly exposed to a significant amount of solar UVR. As with the CWHSP it is possible for workers to have an initial screening to examine the skin for problems or to determine whether they have skin that may be at risk for skin cancer. Screening could be conducted every few years. An example of a country that has included medical screening for outdoor workers is Germany. In July 2019 Germany added a medical screening component to their surveillance of outdoor workers (German dermatologist, personal communication, November 4, 2019). Employers have been mandated by the government to offer skin screening every three years to workers who work outside for more than 1 hour per day for 50 days per year (German dermatologist, personal communication, November 4, 2019). It is not compulsory for the employee to take part in the screening, but it is mandatory that the employer offers it (German dermatologist, personal communication, November 4, 2019). Also employers now must offer protection measures for their workers if the workers are exposed to solar UVR.

Alberta could adopt a screening program for outdoor workers similar to the German model. However, before a screening program can be implemented a clear definition of what an outdoor worker is needs to be established. It would also be helpful to recognize NMSC due to solar UVR as an official OD, to have clear criteria about who would be included in the screening program and perhaps to create an occupational exposure limit for solar UVR. It would be important to include clear scientific evidence to prove why NMSC is included as OD.

Sentinel Event Surveillance:

The Table of Surveillance Practices includes 17 articles or reports that describe sentinel event surveillance [64, 67, 72, 73, 97, 99, 100, 111-120]. A Sentinel Health Event (SHE-Occupational) is a "disease, disability, or untimely death which is occupationally related and whose occurrence may: 1) provide the impetus for epidemiologic or industrial hygiene studies; or 2) serve as a warning signal that materials substitution, engineering control, personal protection, or medical care may be required" [72]. The goal of sentinel surveillance systems is to increase case reporting, identify the risk factors involved and high-risk work sites and then ultimately link preventive interventions to work sites and the broader community [120].

Recently the European Agency for Safety and Health at Work (EU-OSHA) looked at various sentinel surveillance systems in Europe and how they identify emerging work-related health problems and diseases [117]. In most of these systems ODs are typically reported to a central registry and some of these registries are compensation-based while others are not [64]. Many of these registries rely on physicians to report occupational diseases and often the physicians are legally obligated to report a suspected case of OD [64]. Sometimes individuals or even employers can register an OD. It has been noted in the literature that ODs are very often underreported in these systems, but the extent of the underreporting is not clear [64]. The reasons for underreporting to these registries are similar to the underreporting to disease registries and include: difficulties identifying whether the origin of the occupational disease is truly work related (due to the long latency of the disease or due to exposure factors outside of work), physicians not having the knowledge to recognize or diagnose an OD, and also the workers themselves not wanting the disease recognized as work-related [67].

The Norwegian Labor Inspectorate Registry for Work-Related disease (RAS) is an example of a sentinel surveillance scheme. It was designed with the principle of the sentinel health event (SHE) in mind [73]. Since 1977 it is mandatory for physicians to report all suspected and confirmed cases of work-related diseases to the Norwegian Labour Inspectorate (NLI). The main reasoning behind the mandatory reporting is to reduce exposure and eliminate risks with the goal of preventing the progression of disease for the individual case and of preventing the onset of disease in his/her co-worker [19, 73]. A physician reports a suspected or confirmed work-related disease to the NLI, the reported cases are evaluated by the NLI physicians, and the report is entered into an electronic database, the report is then sent to the regional NLI offices and they are responsible for deciding whether the case will be investigated further or an intervention put in place [73]. In many sentinel event systems, the initial reporting of the case is mandatory in principle but not necessarily in practice (RAS, personal communication, November 1, 2019). Underreporting is definitely a problem and in Norway only 3 % (n =561) of the approximately 18,000 registered Norwegian physicians reported to the NLI in 2006 [73].

For a sentinel surveillance system to be created in Alberta a central registry would have to be designed and implemented. Often these registries are linked with workers compensation institutions, so this is a potential option for Alberta. Typically these types of registries would include more than just NMSC, so if modelled on the European examples it would be set up to capture all instances of occupational disease. As the scope of these systems is rather large it may be complex to design and implement and therefore may be an expensive undertaking. Also it would be of utmost importance to consider how to minimize underreporting, so that the surveillance results are not affected by this issue.

Disease Surveillance via data linkage:

The Table of Surveillance Practices includes 15 articles or reports that give a description of how data or record linkage can be used as a method to conduct occupational disease surveillance [48, 49, 62, 74, 97, 102, 121-129]. The key premise of this method is that various data sources are linked to estimate the extent and distribution of occupational disease [48]. In this method large datasets are used and they generally include information on a person's occupation or industry of employment [62]. Identifying information such as name, date of birth and provincial health number can then be linked to various health databases to see whether a particular individual is diagnosed with a disease at some point [62]. This method has been used for occupational disease surveillance and has linked data on individuals with accepted workers compensation and administrative health data (e.g. cancer registry, physician billing data, hospital discharge data) [62].

Ontario recently developed the Occupational Disease Surveillance System (ODSS) and it was developed because there was no existing occupational surveillance system in Ontario that could identify high risk populations and target prevention efforts [74]. It was developed using the method of data linkage: "This system was created in 2016 by linking existing provincial health databases with job information in order to study occupational disease and inform prevention activities. The ODSS identifies at-risk groups of workers, and potential hazardous exposures, within the workplace. Findings from the ODSS contribute to our understanding of occupational disease in Ontario, and can support changes to public health practice"[75]. The ODSS links the following data sources: 1) Workplace Safety and Insurance Board's (WSIB) Time-Loss Claims Database, 2) RPDB – Registered Persons Database, 3) OCR – Ontario Cancer Registry, 4) Ontario Health Insurance Plan (OHIP) eClaims Database, 5) NACRS – National Ambulatory Care Reporting System, 6) DAD – Discharge Abstract Database [74]. "The ODSS is currently being used to examine associations between occupation and industry and 28 cancer sites and 9 non-malignant health outcomes" [74]. A strength of this type of system is that it provides reliable occupational information. However, there are limitations as well: the system only includes individuals who have actually submitted a workers compensation claim and the occupational information is only available at the time the claim is submitted (ODSS, personal communication, November 14, 2019). If an individual changes jobs at some point this would not be taken into account [62].

It is possible to design a similar system to the ODSS in Alberta. Compensation claims to the WCB-AB could be used to create the cohort group. However, if there is a focus on NMSC the challenge would be finding a NMSC data source to link with the cohort. It may be possible to use physician billing data for NMSC (basal and squamous cell carcinoma), however, the physician billing data may not specify exactly what type of skin cancer has been diagnosed. In Ontario NMSC is lumped together under one code, so it would need to be determined whether this is the case in Alberta. Actinic keratosis is coded under other skin diseases, therefore, it would be difficult to include this skin disease in the system. Also currently most Canadian cancer registries do not register incidences of NMSC, therefore a potential occupational surveillance system for NMSC would not be able to link to this data source. It may be worthwhile to investigate whether it would be possible to add NMSC to the cancer registry in Alberta, so that it could be used as a data source. Preliminary research would need to be undertaken to determine exactly which data sources are available with regards to NMSC and whether it would produce the desired surveillance goal.

7.7 Appendix 7: Key informant interview analysis

What are the perceived barriers to developing and implementing an effective occupational surveillance program?

The interviewees identified five key challenges/barriers to the development and implementation of an effective occupational surveillance program: Underreporting/under-participation (due to long latency of disease/difficulty linking disease to work/lack of physician knowledge), funding/competing resources, lack of awareness of risk (workers/employers don't care), mandatory vs voluntary participation or disease legislation, lack of a collection mechanism (cancer registry). Other barriers identified were in regards to cost of preventive measures, lack of an OEL, NMSC not recognized as OD.

1. **Underreporting/under-participation:** Thirteen of the interviewees (59%) mentioned that the underreporting of occupational disease or work related disease as a challenge to the development or implementation of an effective occupational surveillance program. "There is huge underreporting and as you probably know actually that we've been working on this project and on this problem with WHO since 2011". 12 interviewees (55%) noted specifically that occupational diseases are often not reported by physicians due to the long latency of the disease and the difficulty linking the occupational disease to work activities. "More than anything else, the biggest problem is making the link between occupation and health." Physician's lack of knowledge or understanding of occupational diseases also make it difficult to make the link between disease and work. The long latency often means the worker is retired by the time they are diagnosed with an OD, so they or the physician may not be looking at previous job history and how it may relate to the current diagnosis. One participant mentioned that offering incentives to physicians could help counteract underreporting. Also better physician education on topics related to occupational disease may minimize the underreporting.
2. **Funding/competing resources:** Eleven of the participants (50%) mentioned that funding or competing resources are a challenge when designing, implementing and maintaining a surveillance program. "A big one is resourcing/getting the funds/the committed funds/the long term funds to be able to sustain a proper surveillance program." Without proper funding these programs cannot exist. "Funding is or can be a barrier to creating these surveillance programs. If there's no funding, then it's difficult to move forward or if it's, it moves forward on a research grant, there's no guarantee that the funding will continue." Often when government funding is reduced there is a risk that surveillance programs are affected negatively. In the UK the Health and Safety Executive (HSE) reduced funding in the last few years and currently the Center for Occupational and Environmental Health (COEH) only receives enough funding from the Health and Safety Executive (HSE) for the skin and respiratory surveillance schemes (COEH, personal communication, September 26, 2019). It is important that funding sources are available and consistent to maintain this type of work. "Locking in resourcing, and locking in for surveillance programs my own belief is that you need fairly a long term commitment for these things. They can't be set up as a year by year proposition because you just you really just can't deliver a surveillance program." If a program is legislated or if there is policy associated with it, it may have more success in the long run. One participant mentioned that it is important to keep the topic of occupational diseases in the public eye, so that there is more buy in and perhaps associated pressure to keep the programs running.
3. **Lack of awareness of risk:** Seven of the interviewed individuals (32%) flagged the lack of awareness of occupational risk or perhaps the lack of understanding of the risk of solar UVR or of occupational risk. "And maybe one of the barriers I think it might be also intrinsic interest for outdoor workers, whether they are really concerned about the problem. And this is something that they say that

outdoor workers are usually workers who really that they don't care that much." This points to the fact that the employees are not well educated about the risks they face at work and it would be beneficial to ensure that the employees as well as employers are educated on this topic. Better education about occupational risk and how to minimize it would likely lead to employees making the choice to better protect themselves and perhaps be more interested in participating in surveillance projects. Worker/employer apathy can also be a negative influence: "One is apathy. Just getting people interested and committed to doing it." This apathy needs to be addressed and one way to do this is through education or outreach.

4. **Mandatory vs voluntary participation/disease inclusion:** Five of the interviewees (23%) mentioned that it may be beneficial for a program to be mandatory as opposed to voluntary. "It's mandatory for it to exist and for the operators to provide the opportunity or the, you know the information about it, but it's not mandatory for the miners to participate. It is/I will say the first X-ray upon entry into the coal mining industry is mandatory. And then depending upon that result, another two x-rays may be mandatory within the first five years but beyond that, it is all voluntary." There are underlying reasons why employees may choose not to participate in a surveillance program and they include: fear of job loss, fear of discrimination, it is not convenient, fear it is not confidential, fear of finding out they are ill. "I think that having, so from what we saw in that review of exposure registries as an example, certainly the registries that were mandatory, you know, if they were mandatory, and they were legislated, then people I think were more likely to participate. But also, that usually meant that there was some sort of structure or financial backing towards maintaining the system and ensuring that it continued on and I'm thinking of things like the National Dose Registry. That's run at the federal level. So I do think from a participation standpoint, and an operational standpoint, that having policy, ideally sort of legislation behind it is going to make it more likely to be successful in the long run." A surveillance program is more likely to succeed if there is policy/legislation behind it or it is mandated. "Just to kind of back up a bit, I think one of our challenges too in Nova Scotia is that we don't have legislation around UV exposure, and you can interpret, you know, UV as a hazard, but it's not specifically laid out. So I do think that is a challenge for making it a priority within workplaces." Perhaps more workers or employers would take solar UVR exposure more serious with some type of legislation to back it up.

5. **Lack of a collection mechanism:** Five of the participants (23%) mentioned the lack of a collection mechanism for NMSC as a perceived barrier. In many countries NMSC is not registered in their cancer registries, therefore it is difficult to ascertain the actual numbers of NMSC among the general public as well as outdoor workers. An alternate collection mechanism may need to be implemented and this can be difficult to do. **"**So, I would say if we start at the beginning of the continuum, it's, it could be data collection related. So there may be no current mechanisms to collect that information. And so one of the barriers we're facing right now is when we think about non-melanoma. And so we/there is no current mechanism within Alberta. You know, to, to our knowledge, where that is actually being done and so for that work to happen, we need to create like a whole new initiative." Some argue that NMSC is simply too common and difficult to keep track of, but this then means it is difficult to establish the true incidence numbers. "So, you know, we talked before about just how frequent skin cancer is. And that's a barrier because of the overwhelming volume of information that you can, you can suck in can make it really hard for a surveillance program to make sense of what you're seeing. So there are a couple of the barriers, I guess." Another difficulty is collecting information about occupation. It is often difficult to link an OD to a specific occupation. "The data sharing is a huge problem. I know that one of the things that we talked about, I think in Ontario, and that, you know, I don't know how far it's gotten, and but it's the idea that if you've got health care system data, if you've got health system data, there's an opportunity to collect information on

occupation. But that's rarely ever done. And I totally get why because I come from a clinical background, but that, you know, being able to make that linkage at that point would be so, it would open up so many doors for, but I think but if in the absence of that data sharing is a huge problem. And so I think that gets in the way." Currently in Canada physicians do not collect occupational information. The WHO has recognized this problem and has recently developed the International Classification of Diseases 11th Revision (ICD-11) system and have included in this new system the possibility for a physician to code whether occupation is a factor in the diagnosis. The ICD-11 system could be very beneficial for ascertaining the incidences of work related disease and the hope is that ICD-11 is integrated internationally by 2022. [130]

6. **Other barriers:** cost of preventive measures, lack of an OEL for solar UVR, NMSC not recognized as OD.

What are the perceived facilitators to developing and implementing an effective occupational surveillance program?

The interviewees identified seven key facilitators that they perceive are necessary (or highly desirable) for the development and implementation of an effective occupational surveillance program. They include: communication/collaboration, outreach/education, simple reporting process, committed/long term funding, strong team/leadership, physician related factors (education/info collection), legislation/regulatory body. Other facilitators identified were in regards to strong scientific evidence, incentives, and a clear goal for the system.

1. **Communication/collaboration:** Fourteen participants (64%) mentioned that it is important to have good communication/collaboration amongst stakeholders when developing and implementing an occupational surveillance program. "So I think very coordinated efforts across a number of different teams. I think you need people to work together to build the data collection mechanisms, the analytic plans, even how the data is going to be visualized. And that has to be in connection with the people who will be using the information in practice." It is critical to have all stakeholders at the table from the start as this facilitates buy in to the program. This will allow for better understanding of what is going to happen and why information is being collected. "And so I think the other piece at the get go is this stakeholder involvement that is a bit of a softer thing. But you know, it's a bit, you know, if you think of, you know, nothing about us, without us, you know, if you're going to surveil workers for exposure or disease, it, I think it is also critical to have them at the table. Because if they don't understand why this is happening, there is going to be misunderstandings, but they're also less likely to participate, if they don't understand why you're asking them for information or for you know, biological samples, or whatever it is that you're asking. They need to really be active participants in setting it up and be happy and supportive of what the goals are. And also be clear that, you know, this doesn't mean that all of your claims are going to be accepted, or you're not going to have to jump through some of the hoops to get compensation, you know. It helps those types of things, but it also may not depending on how it's set up." Strong communication/collaboration is a key step in the development and implementation of a surveillance program.
2. **Outreach/education:** Nine participants (41%) mentioned that outreach/education is a key component in a successful occupational surveillance program. "I would say over the last five years since we've been outreaching through the industry associations and through our officers. There's definitely more awareness around the work sites and use of protection." Having direct contact with employers and workers is deemed as very positive. "Well, the first thing is, yeah, education, and having conversations and having conversations, like one on one, I think is it goes a long ways

towards this. I mean, it's not the most effective thing. But I, I think I find that when I have individual conversations with individual workers and employers, that's often much more meaningful than some big, you know, promotional thing. I think they support each other. But I do think those face to face conversations are really crucial. Because it's a two way conversation. You're not just blasting information at people." Relationship building is also an important element when implementing a surveillance program. "So I think one of the ways to kind of overcome that are just to try to do, we really focused big on relationship building. And so some of that was doing, for me who was going to be their worksite contact, I had a couple times to meet with them, or do a presentation or do a lunch and learn with the employees themselves. And then was building capacity with them about why this is important. So it wasn't like I was just showing up and asking them to do this. But there was a bigger knowledge of why we were doing this. And so I think that is one way to help overcome that barrier."

3. **Simple reporting process:** Five participants (23%) identified that having a simple reporting process would be helpful in developing and implementing a surveillance program. This would apply only if there is some type of reporting mechanism included in the surveillance system. "And particularly, one day if we could ever have electronic reporting, that would be the cat's meow." Physicians, for example, do not want to be burdened with extra work, so simplifying the reporting process is very important and would likely allow for more buy in. "And we are looking at how we could make it even, because that's part of the problem, how we could make it easier for the doctors just to click from their patient journals, you know, the electronic patient records and we get it into the registry. So we are moving toward that and we are trying to digitalize the entire process." Simplifying the process may make physicians more interested in participating and help combat the underreporting that mar many surveillance programs.
4. **Funding:** Five individuals (23%) mentioned that having guaranteed long term funding is an important step in the implementation process. "And there's really no point trying to design something that's super-duper, if the resourcing just isn't there so. Locking in resourcing, and locking in for surveillance programs my own belief is that you need fairly a long term commitment for these things. They can't be set up as a year by year proposition because you just you really just can't deliver a surveillance program. By definition, it requires length of time and doable follow up." The available funding determines how robust the surveillance system can be and longer term funding equals a more successful and impactful program. "I think funding. It's, it's tough to kind of do a little, little splash and you can show impact. But if you don't have like a sustainability partner or an ongoing source, then it's tough. I think that's just the nature of, of our department and a lot of government programs. It's tough to get your foot in the door and kind of get those long, year, yearlong, 5-10 year commitments to say, here's what the impact you could do in 10 years, rather than these one or two year, not necessarily one offs, we were able to put it in about seven or eight years of solid work. But then again, we want to keep scaling and spreading that. More impact and generate. Because our funders also want to see growth, but at the same time, they have to choose between this work and then another piece of work. So it's tough some times."
5. **Strong leadership:** Four interviewees (18%) felt that they need strong leadership in place to develop an effective occupational surveillance program. "And so I think having a very strong, you know, leadership team who really values the surveillance program and the idea around data driven strategies for evidence informed decision-making is really, really important. And when those agendas are set, really setting the teams up for success and saying, you know, an example would be like being a facilitator for those relationships and saying that doesn't necessarily move forward until this happens. These teams have to come together." A strong team will help to create and maintain

a manageable and successful surveillance program. “I mean getting honestly just like a practical recommendation is to get a really strong team of people who are capable of doing the work and the analyses that needs to be done like who are properly trained and who are/who have the skills for data linkages, for programming, statistical modeling, epidemiology and study design. You know, people who really have the right skill set for doing this kind of work and getting those people in place right from the beginning. So that you don't have to go back in and fix things later. I think is a good sort of/is a very practical but like really key and important lesson that, you know might help people, other people.”

6. **Physician related factors/education:** Four of the participants (18%) mentioned how improved physician education could help link more diseases to occupation. “Um, so I think one thing would be getting medical practitioners in clinical settings more actively involved in occupational disease surveillance in terms of improving their recognition of occupational disease, of skin tumors, of identifying them, recognizing them and being interested or able to report them somehow to some kind of coordinating center or body. And that is something that can be done through a more clinic, clinically focused surveillance program or workplace focused surveillance program with like health and safety representatives and a union or something like that. But it also has benefits for surveillance using administrative data. Because, you know, there are a lot of diseases that we want to look at that we can't because the physician didn't code the disease properly in their diagnostic field in the data. So we actually don't have as many silicosis cases as we think we should, because physicians were coding it under a general, you know, pulmonary fibrosis code that wasn't specific to silica exposure.” Physicians need to understand why surveillance is important and how it can be beneficial to workers in the long run. “I think we just don't/we haven't developed methods and tools to, to make the doctors who are reporting these to the surveillance systems more aware of these things that how surveillance systems can help, not just their patient but beyond the patient.” Currently physicians do not collect occupational information from their patients and it has been suggested that this process change. If occupational information were included in patient files it could be of great benefit to surveillance programs. “Yeah, well, there's no sort of field that is used to describe the occupation of a patient in any administrative data in Ontario. And I don't know if the doctors think it might be work related, but are just thinking, "oh, well, what does that matter for how I bill it". So they just bill it under pulmonary fibrosis, or they just don't recognize that it might be work related at all.”

7. **Legislation:** Four interviewees (18%) felt that having some kind of legislation in place would help to develop an effective surveillance program. “Obviously having a federal mandate, someone saying this needs to be done helps.” This may compel employers or workers to participate and could help minimize underreporting or under-participation. “I think legislation is a good thing to have that it's, I don't know, if voluntary surveillance programs would work. So it's good to have legislation.”

8. **Other facilitators:** The interviewees also alluded to other factors that would facilitate the development of an effective occupational surveillance system including the notification of occupational NMSC, a specific goal for the system, strong scientific evidence, as well as incentives for doctors to participate. “We can clearly say, if doctors wouldn't have notified the cases of occupational cancer without expecting that the cases would be recognized, it would never have happened. That's due to the fact that the number of notifications was rising. And then obviously, also the scientific knowledge was increasing and piling up, and that at any one stage they couldn't refuse anymore. Then finally the Ministry of Labor said okay, we're going to accept that. The same thing is now happening with basal cell carcinoma. I'm sure that it won't last long and we will also have basal cell carcinoma under certain conditions as an occupational skin cancer. And we have

> done a case/control study, which you probably know. I can send it again to you. Which clearly shows actually there's a dose of UV exposure, in which actually the risk doubles for getting basal cell carcinoma. And this was only found in outdoor workers. Not in those who were privately exposed."

What are the key considerations to developing and implementing an effective occupational surveillance program?

During the telephone interviews the participants were asked some specific questions regarding their involvement in the design and implementation of an occupational surveillance program.

What were the motivations behind developing the surveillance program?

Most of the interviewees recognized that there is a specific motivation/goal in place for their respective surveillance programs. Depending on the surveillance program these motivations are determined via a specific mandate/legislation; are for prevention purposes; are to ensure the health, safety and wellness of workers; are to try and detect disease early so that there can be an intervention and something can be done about it; are to better protect and educate workers; are to collect information on exposure to try to determine whether there are sources of exposure that haven't been well recognized; are to give a signal telling us that something more is happening with more workers. It is not possible to design or implement a program without some sort of motivating factor or goal.

Who was involved in the development of the surveillance program?

The majority of interviewees mentioned that multiple groups or stakeholders were involved in the design and implementation process of the occupational surveillance programs. There is typically stakeholder involvement from government (federal, provincial/state), government agencies, researchers, unions, employers, employees, physicians (occupational physicians, specialists, GPs), municipalities, organizations for industry sectors, workers compensation, and regulators. Multi-sectoral involvement is crucial to success. "But ideally, you'd have a working-group of people with multiple skill sets represented. So ideally, I would recommend an occupational physician, you know, someone with a background in health care for work sites. You would want, I would think an epidemiologist, someone who can help design appropriate data gathering techniques and technologies and has an aptitude for handling large datasets. So, also, I think you'd want someone represented from the workplace just so that you can identify any potential barriers to gathering data, you know, and overcoming, you know, just negativity in the workplace, I guess about an intrusive surveillance program. So you definitely want workplace representation. So that would be the three main people you'd want at the sort of at the high level, I guess for the design phase and then you definitely need some means or mechanism of ensuring that data are collected of high quality. You know, there's no point having a surveillance program if the data are not high quality data; consistent, and reproducible and clean and verifiable. So you need some sort of data management person in there as well who will care about that and ensure that it's high quality. And then at the end of the day, you'll need an analyst of some skill set; statistician or data analyst to actually crunch the numbers, ideally under the oversight of the epidemiologist or the occupational health physician, but obviously the epidemiologist to, you know, to make sure that the comparisons are valid and that the right questions are being answered."

What exposures/outcomes are included in the surveillance program?

There were numerous exposures/outcomes included in the various occupational surveillance systems. There was no particular pattern here other than there was some type of exposure or outcome that was focused upon. It is important to define the type of exposure or disease/diseases included in the surveillance program from the start.

Is there policy developed that supports or requires the surveillance program?

In many cases there was some type of policy in place that supported the surveillance program and it was recognized that it is helpful if the program is mandated/legislated.

What were the steps taken to develop and implement the program?

Some suggestions were made on steps to follow in the development and implementation of an occupational surveillance program. One interviewee summed up what steps should be taken as follows: "And so in terms of the steps that were taken, that I'm aware of, it was really developing a, like concept for what is actually needed. Really figuring out who the key players and partners are going to be. And then really starting to develop kind of a scientific protocol around what are the/what is the science behind the surveillance that's going to be implemented. So what are the key indicators? How will they be defined? How will we from an analytic standpoint, you know, be analyzing this data so that it's analyzed in a very, you know, robust way so that what we're reporting is accurate. Also, you know, how/what data sources do we actually need and where are there data gaps. And so, part of our work is really focused on working to create innovations around data collection, and then the other part is focused on how we actually present that information". Another participant suggested the following: "Yeah, I guess the first thing I guess you need to do is identify who are the stakeholders in this. You know, just work out exactly who needs to sit around the table. And then I guess you really need to define carefully what is the question you're trying to answer/what is the problem you're trying to solve or the problem you're trying to measure. And be really clear about that so that people, everyone agrees that that's the priority. I think an early step is to work out what resources you have available, because you can have a Rolls Royce model or you can have a, you know, a Fiat 500 model, but it depends on what resources are available. And there's really no point trying to design something that's super-duper, if the resourcing just isn't there so. Locking in resourcing, and locking in for surveillance programs my own belief is that you need fairly a long term commitment for these things. They can't be set up as a year by year proposition because you just you really just can't deliver a surveillance program. By definition, it requires length of time and doable follow up. So I think that's important as well. So they are the sort of big picture steps. Once there's agreement on what the scope and scale and duration is, then the next step is to actually have a design phase of preparing what the actual data capture looks like and how data will be recorded. And I think you need to build in a pilot phase for that as well to make sure that you can road test everything. See how the systems work, identify any flaws, or bugs or anything like that, and then, and then you can roll it out more generally. And then, you know, at a period of time, maybe 18 months/two years in, then you need to do a sort of midterm evaluation and just make sure that it's all working, that the processes are working properly, that it's fit the purpose, the quality of the data are high. And then you can have the sort of three to five year goal of then actually reviewing the data and looking at trends in the data and working out where you are. So it's a fairly long term proposition and there are defined steps along the way." The steps need to be clearly defined so that everyone knows where the program is at and where it is heading.

Is sun exposure/NMSC included?

Sun exposure or NMSC was not included in the majority of the surveillance programs discussed, but a number of the interviewees felt that NMSC should be included in surveillance. "So I can imagine that for outdoor workers there, it would be a high priority. You know, I really would think it would be in most parts of the world, it would be something that would be important because it's definitely a preventable and known cause of cancer. It's something we can do something about and it's worth preventing. Skin cancer is not a fun thing to have.”

What data sources were used?

There were various data sources used depending on the program. Some of these included health administrative data (this can include physician billing data, discharge abstract data, national ambulatory care reporting system), a cancer registry, population based surveys, workers compensation claims/data, registered persons data. It was noted that it has been a challenge linking this type of data to occupation. “But I think, I actually think that the advent of data linkage and the advent of, you know, sort of new technologies that we're getting: smartphone apps and other things can lessen the barriers and facilitate this kind of surveillance work.”

What tools are used to evaluate effectiveness?

Some of the interviewees do evaluate their surveillance systems but often not in a specific systematic way. Evaluation is an important part of the design and implementation of an occupational surveillance program. One interviewee described how evaluation should be undertaken. “Yeah, look, ideally it should be done ideally independently. So having other people come in and evaluate. And I guess there is probably two main steps in evaluation; one sort of evaluating the processes and, and running checks over the actual mechanics of how the program works. And then I guess the second part is evaluating how it's actually performed in practice in the field at the time. And I guess the process evaluation can happen earlier in the scheme of things. You can do that, you know, after 12-18 months to make sure that you know, the systems are working appropriately. That the, you know, the sort of key performance indicators (KPIs) are being met that you know, the whatever it is that you're trying to measure the number, you know, the number of events you're trying to capture or the number of work sites in which the program is situated or whether it's a state based or province, province based thing. So, you know, just going through and having an independent evaluator come through and assess just how well it's meeting its process commitments. And then the sort of performance evaluation would come later on. And I guess that's more of an analytical and I guess, scientific approach. And that probably doesn't have to be done by independent people. That can be done by the committee itself or by the by the oversight people. But I guess then you just trying to really work out; what are these data telling us. Is it different from what we expected? If it is different is it different because we made mistakes. Or is it different because the data are right. And we know that whatever differences we're seeing from expectation are due to factors we hadn't foreseen. So that's when it becomes informative at that point.”

How are results disseminated?

Most of the participants mentioned that their programs have engaged in formal result dissemination. This is often in the form of newsletters, quarterly reports, annual reports, peer reviewed literature, fact sheets, on websites, abstracts, or presentations to stakeholders. The dissemination piece is a crucial component of a surveillance program. “I think, I think the dissemination part is really critical. I think it's where we often fall down is at the end. We are just so exhausted. We forget to tell people what we found and I think that that sort of, is a really important thing to do. So I think, I think at the end of the day, regardless of what you find good or bad or indifferent make the most of those findings and get them out there because that perpetuates the need for more of this kind of activity and it helps other people who are trying to avoid the same pitfalls that we sometimes make.”

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