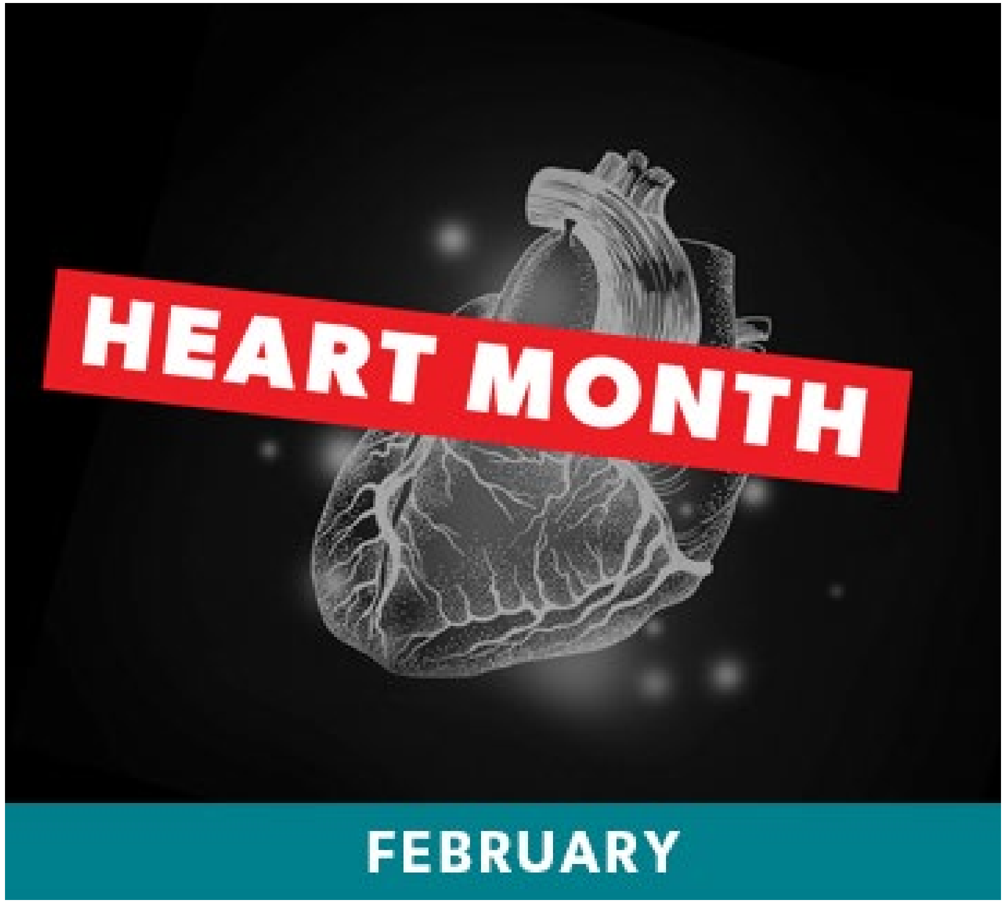
The physiochemical characteristics of McIntyre Powder and the impacts on cardiovascular disease among a cohort of Ontario underground mine workers



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35 YEARS 1989-2024

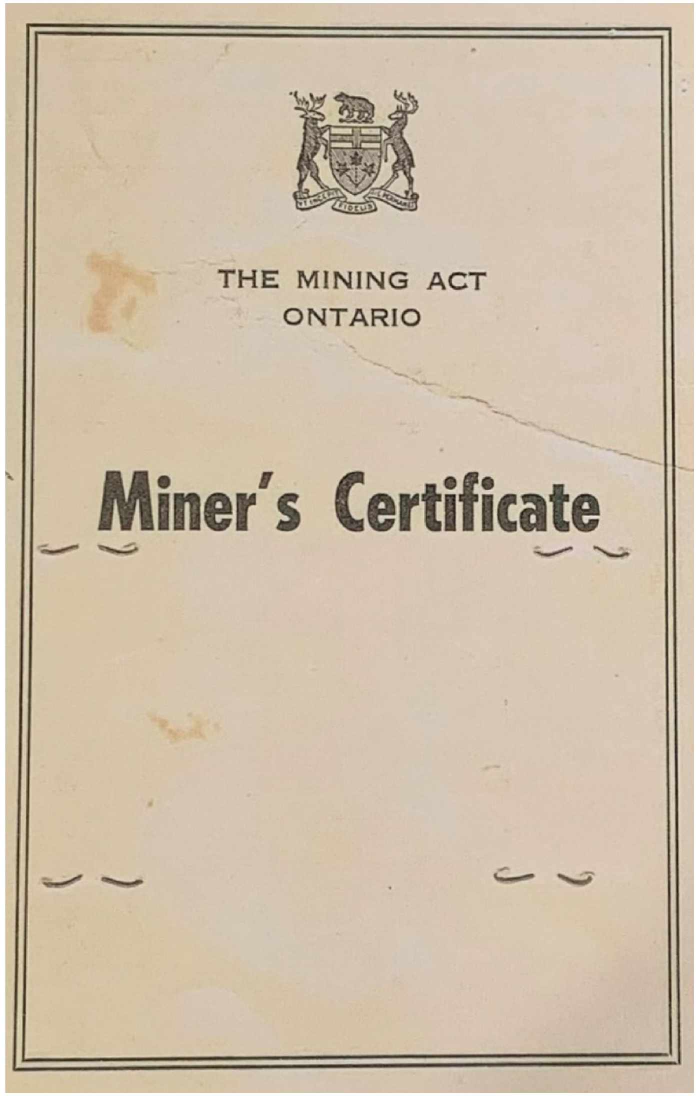
Andrew Zarnke, PhD

Outline

- History and background of McIntyre Powder usage
- McIntyre Powder and it's potential contributions to cardiovascular disease risk
- Incidence of cardiovascular disease in a cohort of mine workers exposed to ultrafine aluminum powder in Ontario, Canada

History and Background

- In 1926 Silicosis became a compensable occupational disease
- There were very high rates of silicosis in Ontario gold and uranium mines
- In order to track mine workers and their health the Mining Master File was created
- The MMF card contained information on periods of employment at specific mine sites, ore type, job title, MP exposure and pre-employment medical exams and annual chest x-ray results
- During this same time McIntyre Powder (MP) was developed by the McIntyre Research Foundation as a prophylaxis to silica exposure to decrease the occurrence of silicosis in Ontario mines.

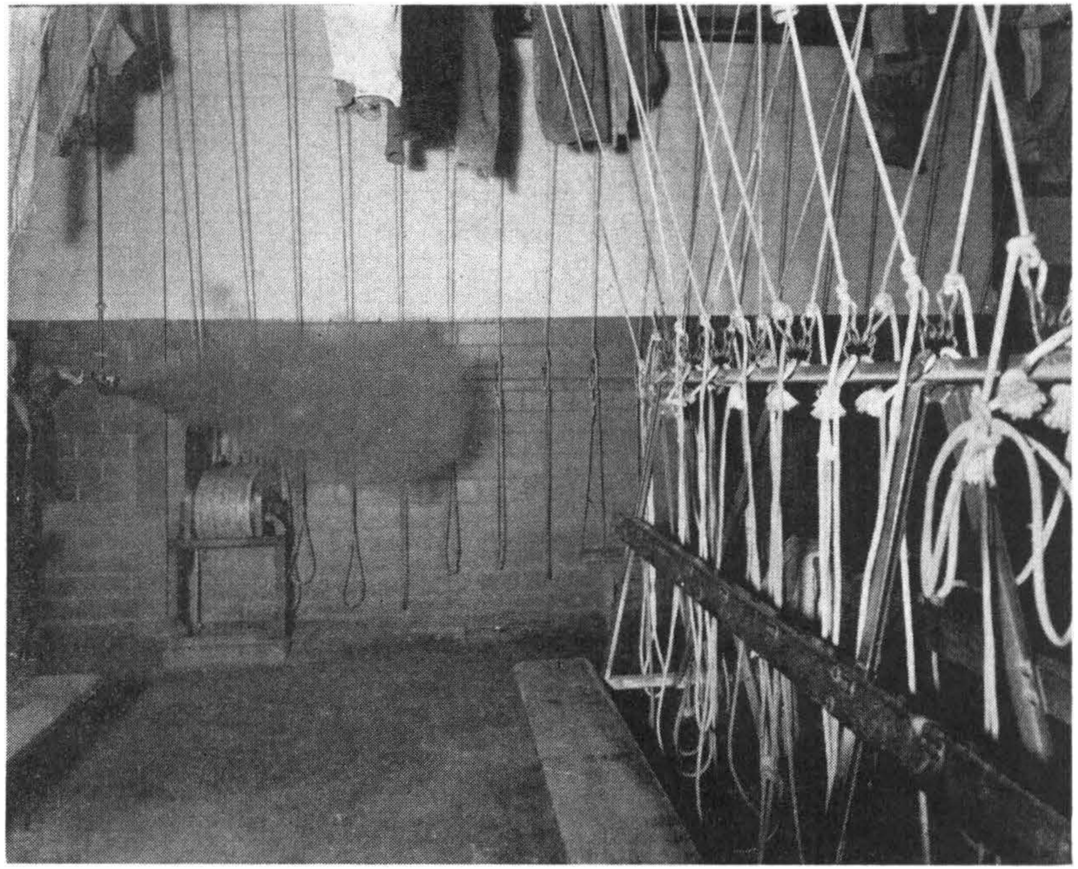


History and Background

- “Official” use of MP began in December 1943 at McIntyre - Porcupine Mines in Timmins, ON (first licensee) and continued until approximately 1980

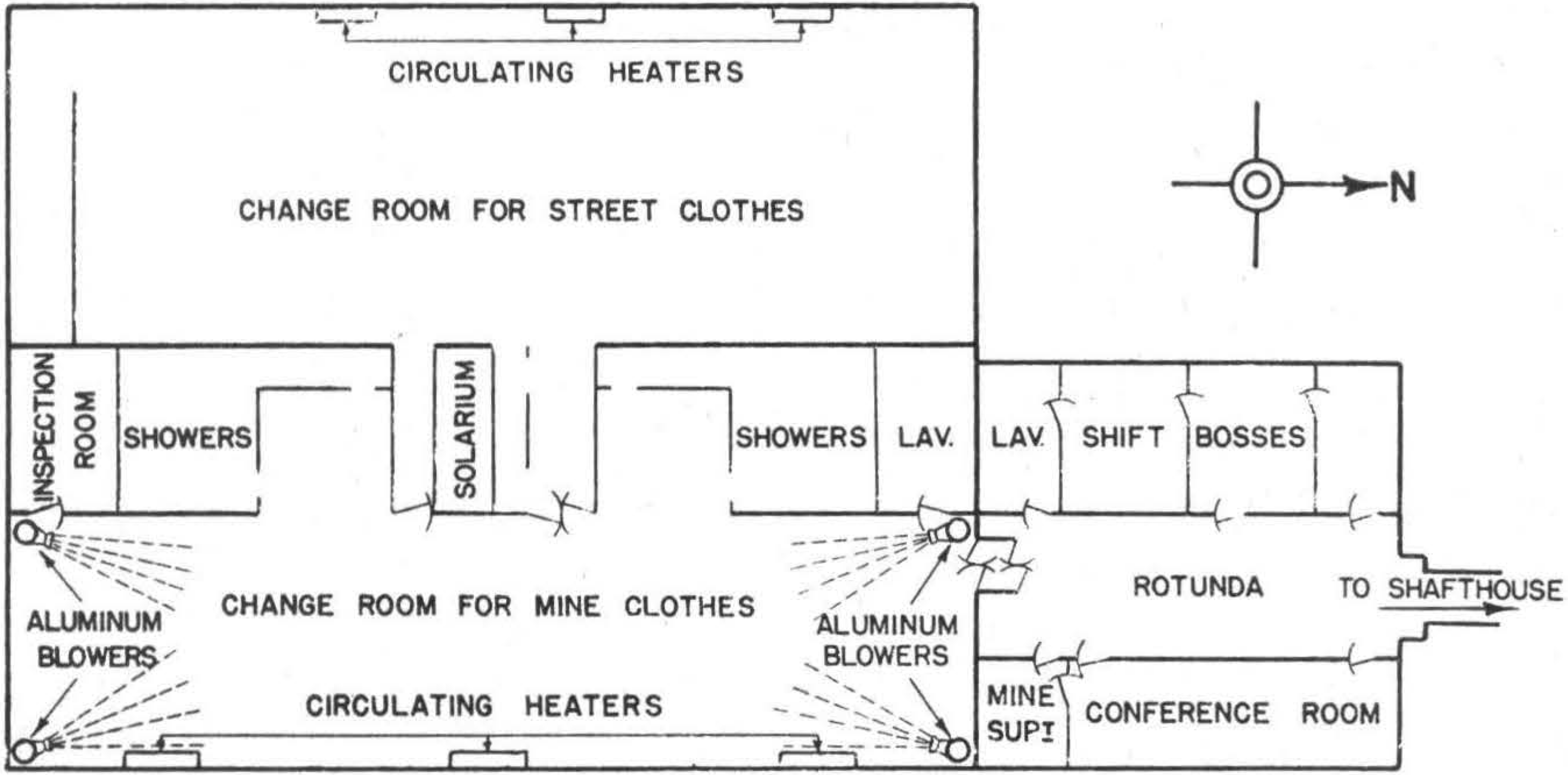
- McIntyre Powder treatment was mandatory to work underground

McIntyre Powder Exposure



Recommended Dose:

- 1g per 1000 ft^3 for 10 minutes
- 35.3 mg/m^3 for 10 minutes
- 0.74 mg/m^3 time weighted for 8 hours



ARRANGEMENTS FOR ALUMINUM PROPHYLAXIS IN McINTYRE DRYHOUSE

McIntyre Powder and CVD Risk – Peters et al. 2013

OEM Online First, published on October 8, 2013 as 10.1136/oemed-2013-101487

Workplace

ORIGINAL ARTICLE

Long-term effects of aluminium dust inhalation

Susan Peters,[1] Alison Reid,[1,2] Lin Fritschi,[1] Nicholas de Klerk,[2,3] A W (Bill) Musk[2,4]

- Linked miner's health record cards to the Western Australian Registrar General's Mortality Database
- Used case definition for cardiovascular disease, cerebrovascular disease, Alzheimer's disease, and pneumoconiosis
- Standardized Mortality Ratios (SMR's) were estimated by comparison to the general male population
- Hazard ratios (HR) were estimated by comparison to the never exposed group

McIntyre Powder and CVD Risk

Table 1 SMRs overall and by exposure to aluminium dust among underground gold miners (1961–2009)

	Full cohort (n=1894)			Never aluminium (n=1247)			Ever aluminium (n=647)		
	42 780 person years			30 033 person years			12 747 person years		
Cause of death	n	SMR	95% CI	n	SMR	95% CI	n	SMR	95% CI
Cardiovascular disease	508	1.31	1.20 to 1.43	285	1.26	1.12 to 1.41	223	1.38	1.21 to 1.57
Cerebrovascular disease	136	1.38	1.16 to 1.63	82	1.43	1.16 to 1.78	54	1.30	1.00 to 1.70
Alzheimer's disease	16	1.08	0.66 to 1.76	8	0.89	0.44 to 1.78	8	1.38	0.69 to 2.75
Pneumoconiosis	73	16.1	12.8 to 20.2	36	13.5	9.76 to 18.8	37	19.6	14.2 to 27.1

Peters, S., et al., *Long-term effects of aluminium dust inhalation.* Occup Environ Med, 2013. **70**(12): p. 864-8.

McIntyre Powder and CVD Risk

Table 2 HRs for duration of aluminium dust inhalation among underground gold miners

	Never aluminium (reference)	Ever aluminium			1–9 years aluminium			10+ years aluminium			Continuous (years of aluminium dust exposure)	
	30 033 person years	12 747 person years			6782 person years			5965 person years				
Cause of death	n	n	HR*	95% CI	n	HR*	95% CI	n	HR*	95% CI	HR*	95% CI
Cardiovascular disease	285	223	1.19	0.99 to 1.44	121	1.23	0.99 to 1.54	102	1.15	0.91 to 1.45	1.02	1.00 to 1.04
Cerebrovascular disease	82	54	0.89	0.63 to 1.27	25	0.79	0.51 to 1.25	29	1.01	0.65 to 1.55	0.99	0.96 to 1.03
Alzheimer's disease	8	8	2.79	0.88 to 8.82	4	2.37	0.63 to 8.88	4	3.59	0.88 to 14.7	1.11	0.99 to 1.24

*All HRs are adjusted for year of birth.

Peters, S., et al., *Long-term effects of aluminium dust inhalation.* Occup Environ Med, 2013. **70**(12): p. 864-8.

PM2.5 and Cardiovascular Disease

In 2018 the WHO reported estimates of 7 million premature deaths per year caused by exposure to fine particulates.

Lelieveld *et al.* 2019 estimated that in 2015 there were 9 million deaths worldwide attributable to air pollution. With the strongest associations attributable to $PM_{2.5}$

Put this into perspective:

The WHO estimates that the excess death rate from tobacco smoking is 7.2 million per year.

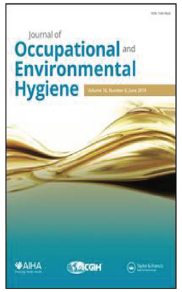
Therefore, $PM_{2.5}$ exposure could be considered a larger risk factor for mortality than smoking.

Pope and Dockery, 2006

Table 2. Comparison of percentage increase (and 95% CI) in relative risk of mortality associated with long-term particulate exposure.

			Percent Increases in Relative Risk of Mortality (95% CI)		
Study	**Primary Sources**	**Exposure Increment**	**All Cause**	**Cardiopulmonary**	**Lung Cancer**
Harvard Six Cities, original	Dockery et al. 1993[26]	10 μg/m^3 $PM_{2.5}$	13 (4.2, 23)	18 (6.0, 32)	18 (−11, 57)
Harvard Six Cities, HEI reanalysis	Krewski et al. 2000[177]	10 μg/m^3 $PM_{2.5}$	14 (5.4, 23)	19 (6.5, 33)	21 (−8.4, 60)
Harvard Six Cities, extended analysis	Laden et al. 2006[184]	10 μg/m^3 $PM_{2.5}$	16 (7, 26)	28 (13, 44)[a]	27 (−4, 69)
ACS, original	Pope et al. 1995[27]	10 μg/m^3 $PM_{2.5}$	6.6 (3.5, 9.8)	12 (6.7,17)	1.2 (−8.7, 12)
ACS, HEI reanalysis	Krewski et al. 2000[177]	10 μg/m^3 $PM_{2.5}$	7.0 (3.9, 10)	12 (7.4, 17)	0.8 (−8.7, 11)
ACS, extended analysis	Pope et al. 2002[179] Pope et al. 2004[180]	10 μg/m^3 $PM_{2.5}$	6.2 (1.6, 11)	9.3 (3.3, 16) 12 (8, 15)[a]	13.5 (4.4, 23)
ACS adjusted using various education weighting schemes	Dockery et al. 1993[26] Pope et al. 2002[179] Krewski et al. 2000[177]	10 μg/m^3 $PM_{2.5}$	8–11	12–14	3–24
ACS intrametro Los Angeles	Jerrett et al. 2005[181]	10 μg/m^3 $PM_{2.5}$	17 (5, 30)	12 (−3, 30)	44 (−2, 211)
Postneonatal infant mortality, U.S.	Woodruff et al. 1997[185]	20 μg/m^3 PM_{10}	8.0 (4, 14)	–	–
Postneonatal infant mortality, CA	Woodruff et al. 2006[186]	10 μg/m^3 $PM_{2.5}$	7.0 (−7, 24)	113 (12, 305)[c]	–
AHSMOG[b]	Abbey et al. 1999[187]	20 μg/m^3 PM_{10}	2.1 (−4.5, 9.2)	0.6 (−7.8, 10)	81 (14, 186)
AHSMOG, males only	McDonnell et al. 2000[188]	10 μg/m^3 $PM_{2.5}$	8.5 (−2.3, 21)	23 (−3, 55)	39 (−21, 150)
AHSMOG, females only	Chen et al. 2005[189]	10 μg/m^3 $PM_{2.5}$	–	42 (6, 90)[a]	–
Women's Health Initiative	Miller et al. 2004[190]	10 μg/m^3 $PM_{2.5}$	–	32 (1, 73)[a]	
VA, preliminary	Lipfert et al. 2000, 2003[190,192]	10 μg/m^3 $PM_{2.5}$	0.3 (NS)[d]	–	–
VA, extended	Lipfert et al. 2006[193]	10 μg/m^3 $PM_{2.5}$	15 (5, 26)[e]	–	–
11 CA counties, elderly	Enstrom 2005[194]	10 μg/m^3 $PM_{2.5}$	1 (−0.6, 2.6)	–	–
Netherlands	Hoek et al. 2002[195]	10 μg/m^3 BS	17 (−24, 78)	34 (−32, 164)	–
Netherlands	Hoek et al. 2002[195]	Near major road	41 (−6, 112)	95 (9, 251)	–
Hamilton, Ontario, Canada	Finkelstein et al. 2004[197]	Near major road	18 (2, 38)	–	–
French PAARC	Filleul et al. 2005[198]	10 μg/m^3 BS	7 (3, 10)[f]	5 (−2,12)[f]	3 (−8,15)[f]
Cystic fibrosis	Goss et al. 2004[200]	10 μg/m^3 $PM_{2.5}$	32 (−9, 93)	–	–

McIntyre Powder particle characterization



Journal of Occupational and Environmental Hygiene

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Physical and chemical characterization of McIntyre Powder: An aluminum dust inhaled by miners to combat silicosis

Andrew Zarnke, Pat E. Rasmussen, Marie-Odile David, Housam Eidi, Konnor Kennedy, Kevin Hedges, Todd Irick, Christopher Thome, Jake Pirkkanen & Douglas Boreham

Both Studies in agreement:

- 100% below 2.5 µm ($PM_{2.5}$)
- 12% below 100 nm (nano particles)

Chemical and Physical Characterization of McIntyre Powder using Inductively Coupled Plasma Mass Spectroscopy and Electron Microscopy

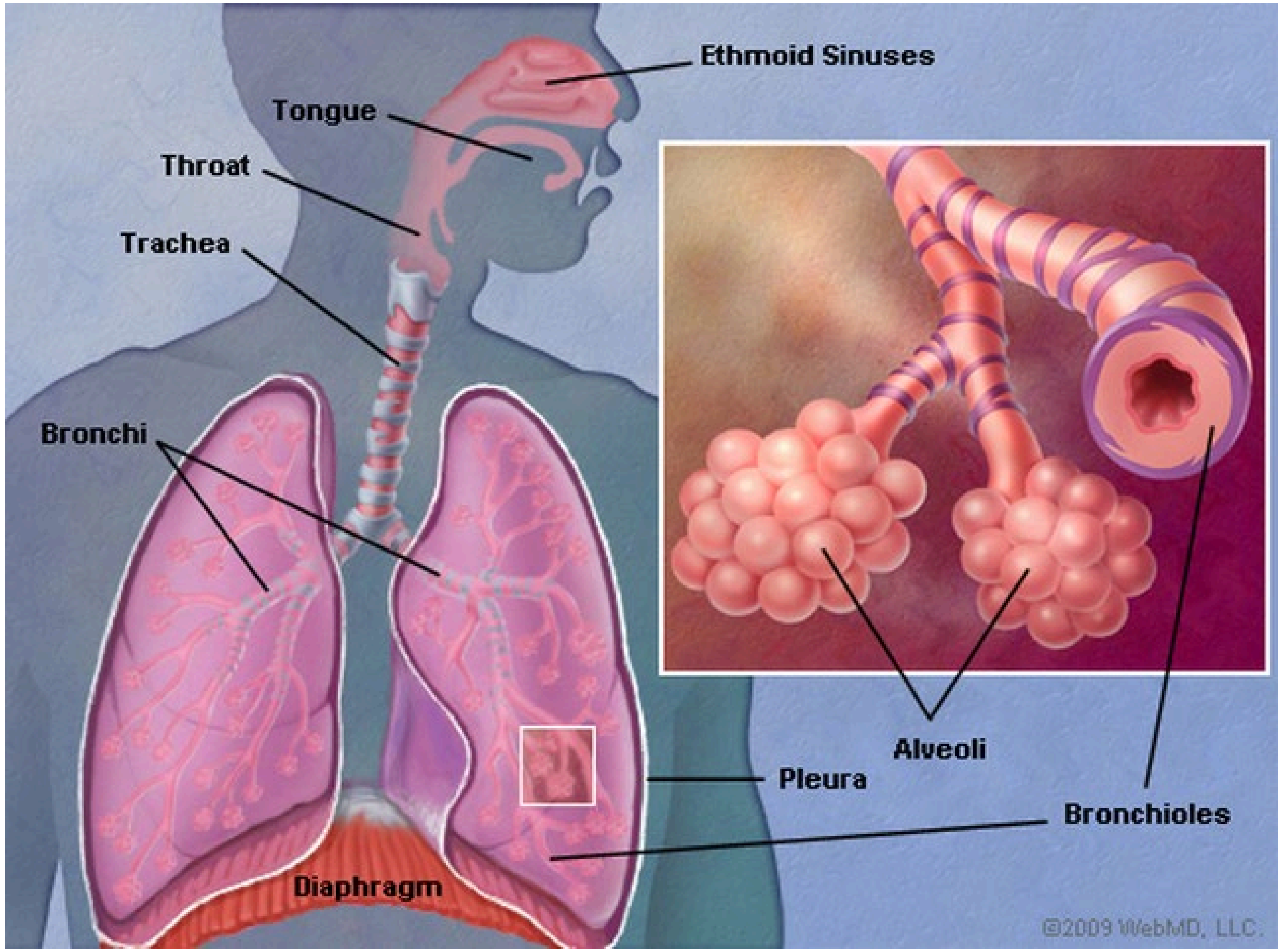
Article *in* American Journal of Preventive Medicine and Public Health · January 2020

DOI: 10.5455/ajpmph.20190927030605

Factors Influencing CVD Risk from Inhaled Substances

Particle Clearance Mechanisms:

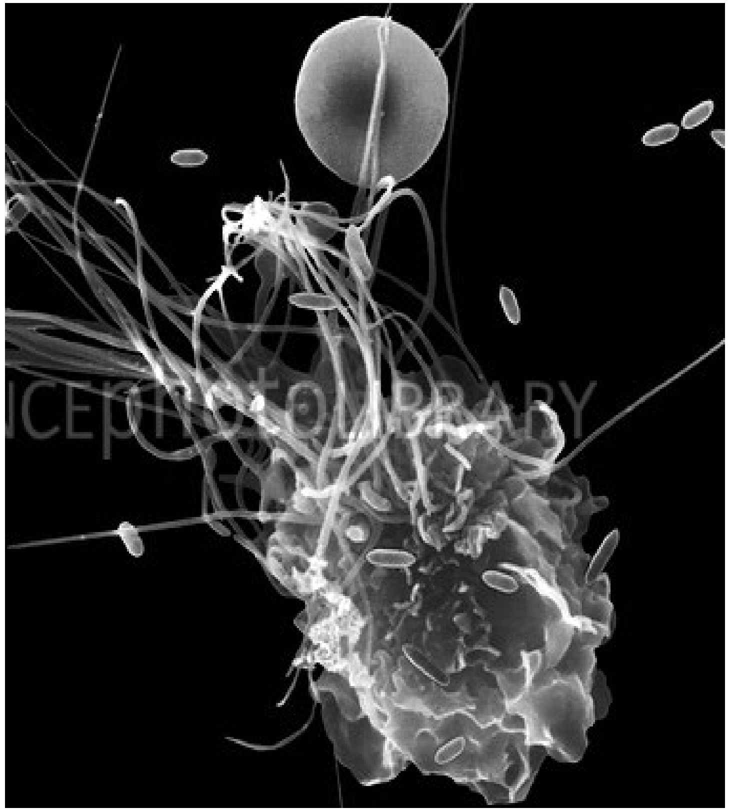
- Larger particles (>10µm) have a higher probability of being filtered out in the nasal passages
- Smaller particles deposited in the upper airways are removed within **hours** by the mucociliary escalator
- Particles ≤2.5µm have a higher probability of penetrating the lower airways (alveoli)
- Alveoli are composed of unciliated smoot epithelium and particle clearance is much slower (≥24 hrs)



Lung Overload?

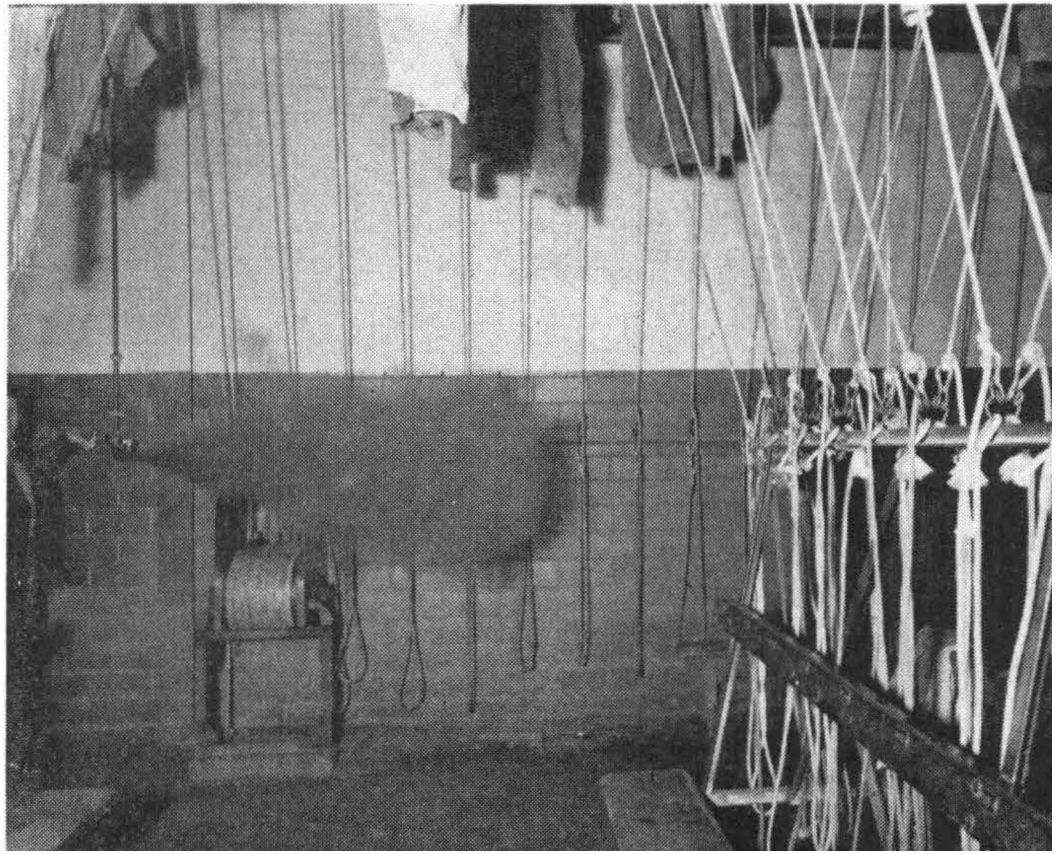
Lung Overload

- Alveolar macrophages become overwhelmed with particles
- Lung clearance is greatly reduced or absent
- Smaller particles also accelerate the process of lung overloading
- Fine and ultrafine particles are more easily translocated out of the lung through the circulatory system
- Inflammatory spill-over into the circulatory system



Other exposures in mining linked to CVD

- Respirable crystalline silica
- Heat stress
- Diesel engine particulate matter
- Nitrogenous byproducts from blasting
- Stress from a dangerous work environment



McIntyre Powder and Cardiovascular Disease

- Scientific evidence suggests there is a dose response relationship between exposure to $PM_{2.5}$ and cardiovascular disease.
- The small particle sizes and high dose rate of the MP favour conditions for lung overload.
- Lung overload conditions increase the probability of MP particle translocation
- Inhibited lung clearance mechanisms from MP exposure would have likely enhance the effects from subsequent dust, radon, silica and diesel particulate exposures experienced in the mining environment.

Incidence of Cardiovascular Disease in a Cohort of Mine Workers Exposed to Ultrafine Aluminum Powder in Ontario, Canada

Andrew Zarnke, PhD, Sarah Rhodes, PhD, Nathan DeBono, PhD, Colin Berriault, MA, Sandra C. Dorman, PhD

CROSH CRSST
centre for research in occupational safety and health at Laurentian University | centre de recherche sur la santé et sécurité au travail à l'Université Laurentienne

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Occupational Cancer Research Centre

LaurentianUniversity
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Methods – Case ascertainment

- Mine workers in the Mining Master File (MMF) were identified in the Registered Person Database (RPDB) to obtain Ontario health card numbers

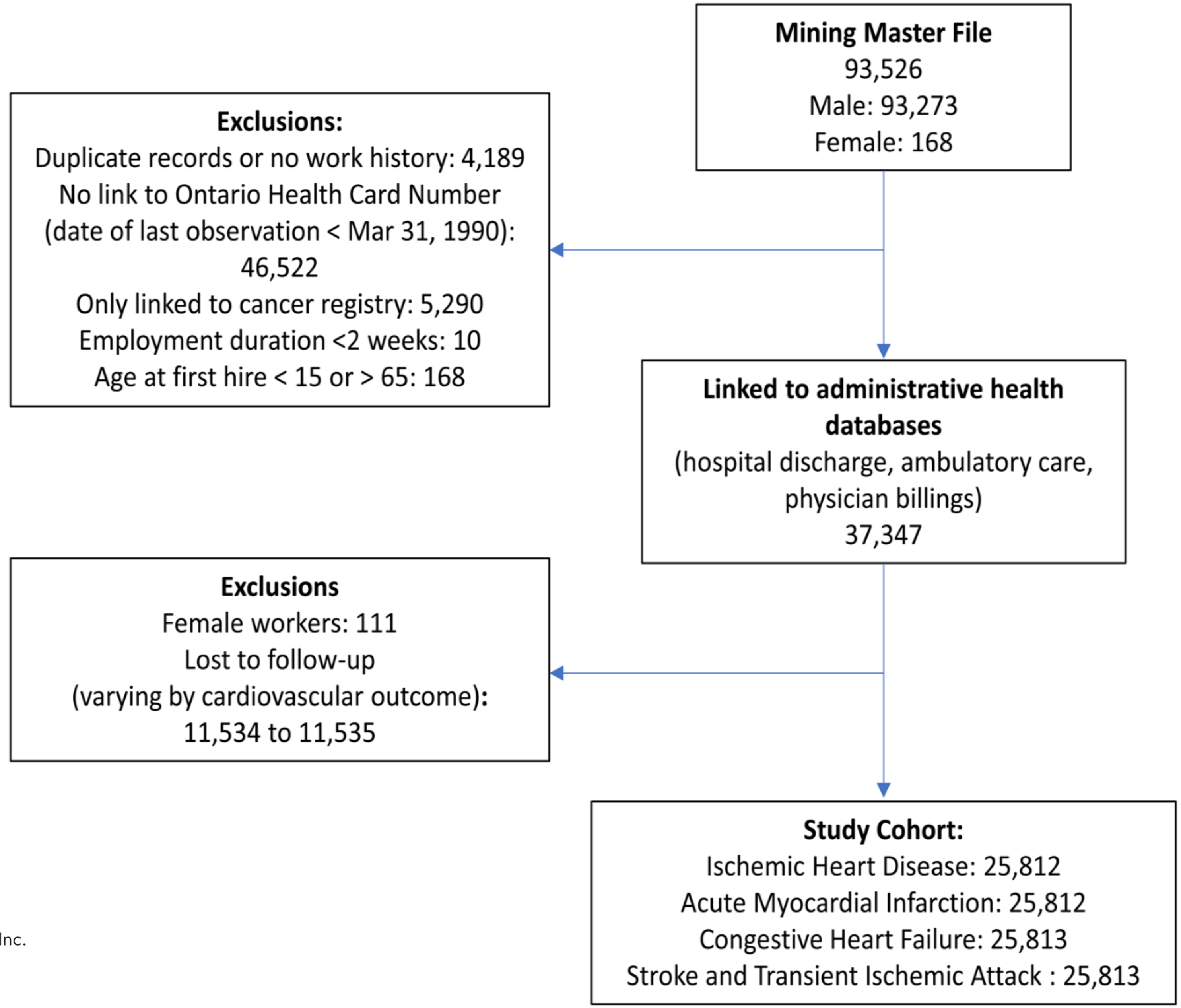
- Mine workers health card numbers were used to create a linkage to the Ontario health databases to ascertain cases of cardiovascular disease.

These databases include:
Discharge Abstract Database (DAD) – hospital visits
Ontario Health Insurance Plan (OHIP) claims database – physician billing
National Ambulatory Care Reporting System (NACRS) – emergency room visits

Methods – Case definitions

- Ischemic Heart Disease (IHD)
- Acute Myocardial Infarction (AMI)
- Congestive Heart Failure (CHF)
- Stroke and Transient Ischemic Attacks (STIA)

- Tu K, Mitiku T, Lee DS, Guo H, Tu JV. Validation of physician billing and hospitalization data to identify patients with ischemic heart disease using data from the Electronic Medical Record Administrative data Linked Database (EMRALD. *Canadian Journal of Cardiology.* 2010;26(7):e225-e228.
- Tu K, Mitiku T, Guo H, Lee D, Tu J. Myocardial infarction and the validation of physician billing and hospitalization data using electronic medical records. *Chronic Diseases and Injuries in Canada.* 2010;30(4).
- Schultz SE, Rothwell DM, Chen Z, Tu K. Identifying cases of congestive heart failure from administrative data: a validation study using primary care patient records. *Chronic diseases and injuries in Canada.* 2013;33(3).
- Tu K, Wang M, Young J, et al. Validity of administrative data for identifying patients who have had a stroke or transient ischemic attack using EMRALD as a reference standard. *Canadian Journal of Cardiology.* 2013;29(11):1388-1394.


Mining Master File
93,526
Male: 93,273
Female: 168
Exclusions:
Duplicate records or no work history: 4,189
No link to Ontario Health Card Number
(date of last observation < Mar 31, 1990):
46,522
Only linked to cancer registry: 5,290
Employment duration <2 weeks: 10
Age at first hire < 15 or > 65: 168
Linked to administrative health databases
(hospital discharge, ambulatory care, physician billings)
37,347
Exclusions
Female workers: 111
Lost to follow-up
(varying by cardiovascular outcome):
11,534 to 11,535
Study Cohort:
Ischemic Heart Disease: 25,812
Acute Myocardial Infarction: 25,812
Congestive Heart Failure: 25,813
Stroke and Transient Ischemic Attack : 25,813

Exposure Assessment

McIntyre Powder personal exposure classification

There were two sources of MP exposure information for each mine worker in the MMF:

1 - self-reported MP exposure on the annual medical exam, and the second was

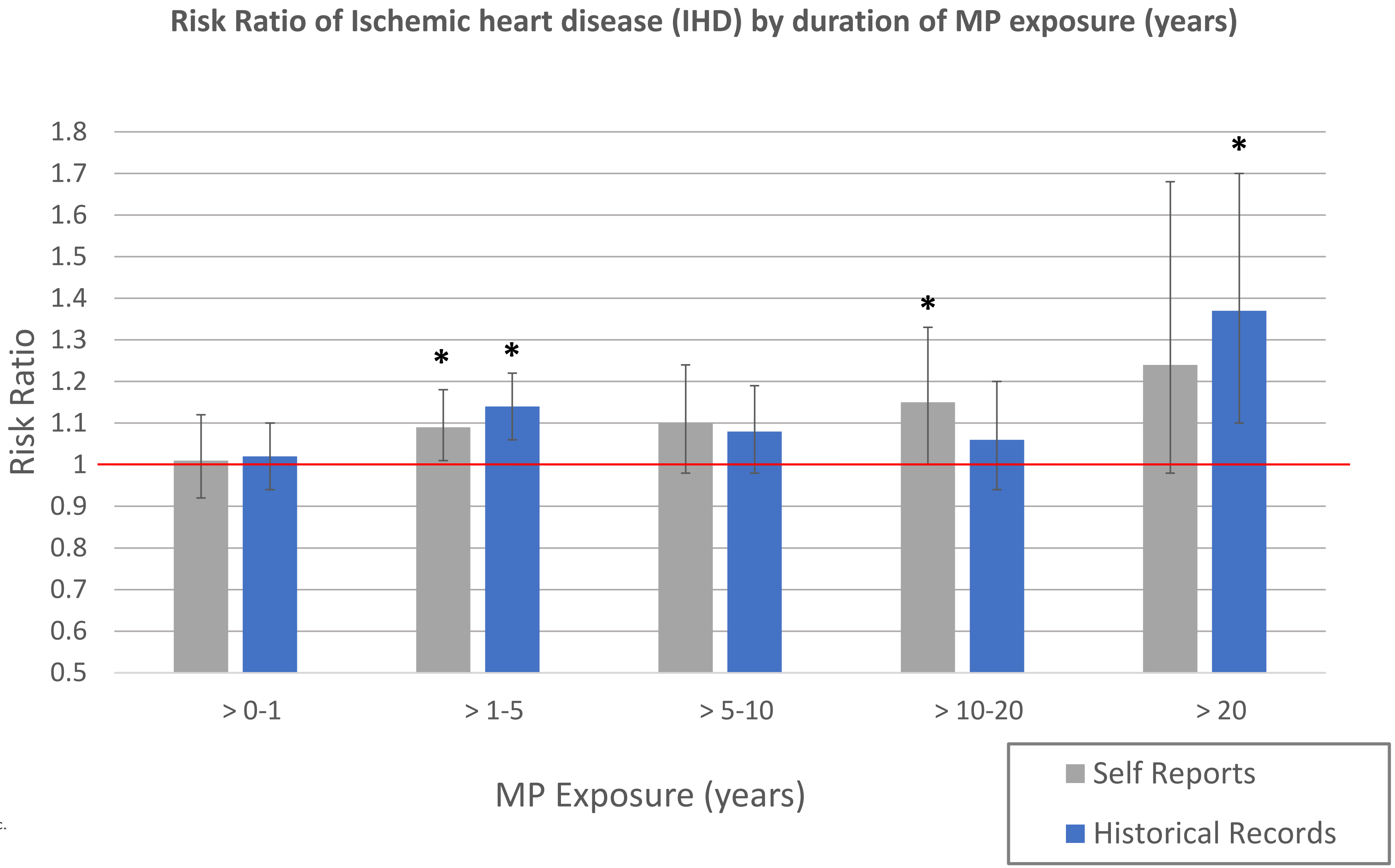
2 - the MMF work history compared to the list of 51 mine sites (originally 48).

Results

Table 4-2: Number and proportion of workers exposed to McIntyre Powder in the study cohort.

MP exposure	Self-reports	Historical records
	N(%)	N(%)
Exposed	5823 (23)	9310 (36)
Only before 1956	261 (1)	292 (1)
Ever after 1956	5562 (22)	9018 (35)
Only after 1956	4826 (19)	7992 (31)
Never exposed	19990 (77)	16503 (64)
Cumulative duration (years) of MP exposure		
> 0-1	1602 (6)	3564 (14)
> 1-5	2570 (10)	3271 (13)
> 5-10	945 (4)	1429 (6)
> 10-20	585 (2)	829 (3)
> 20	121 (0.5)	217 (1)

Results



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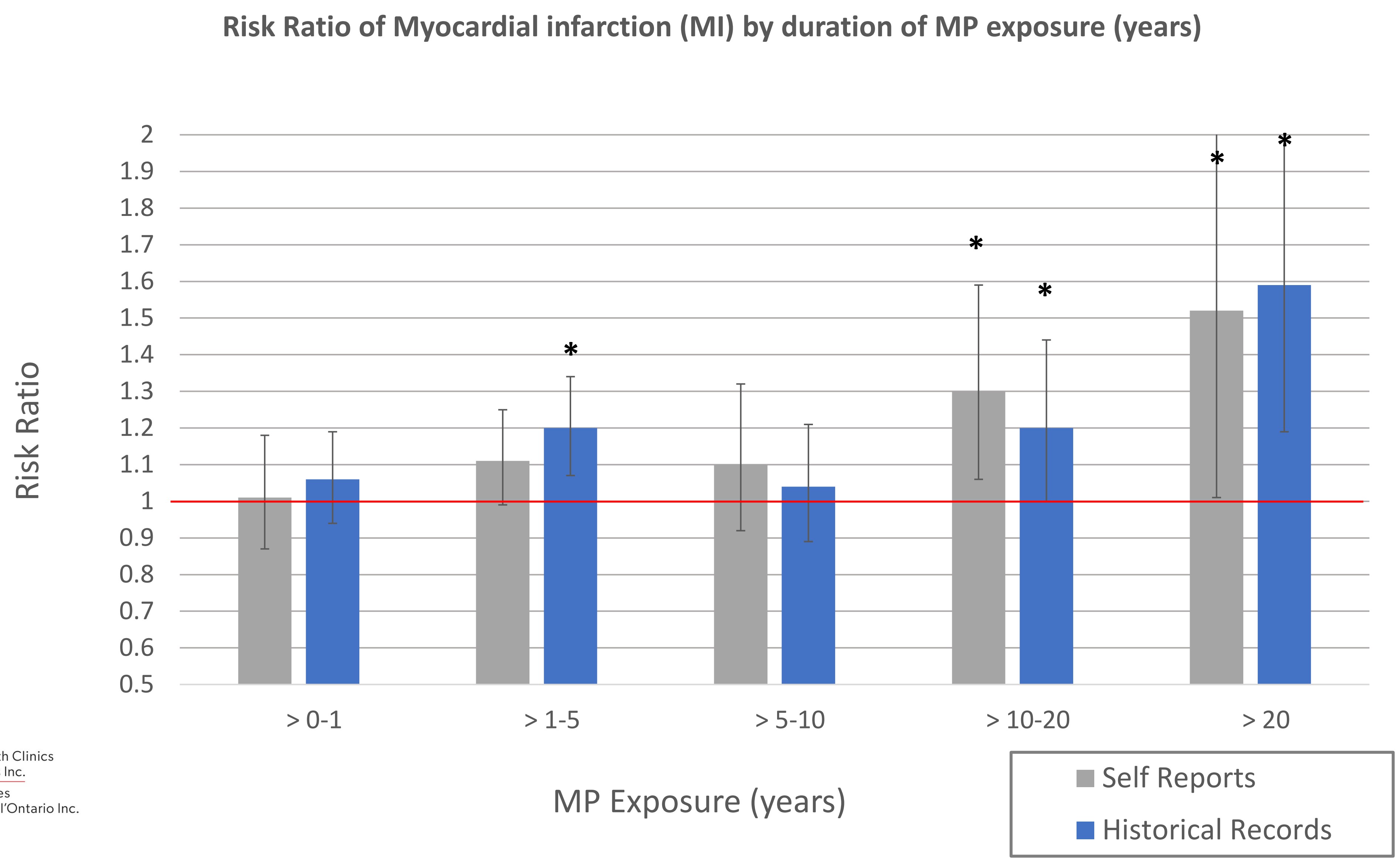

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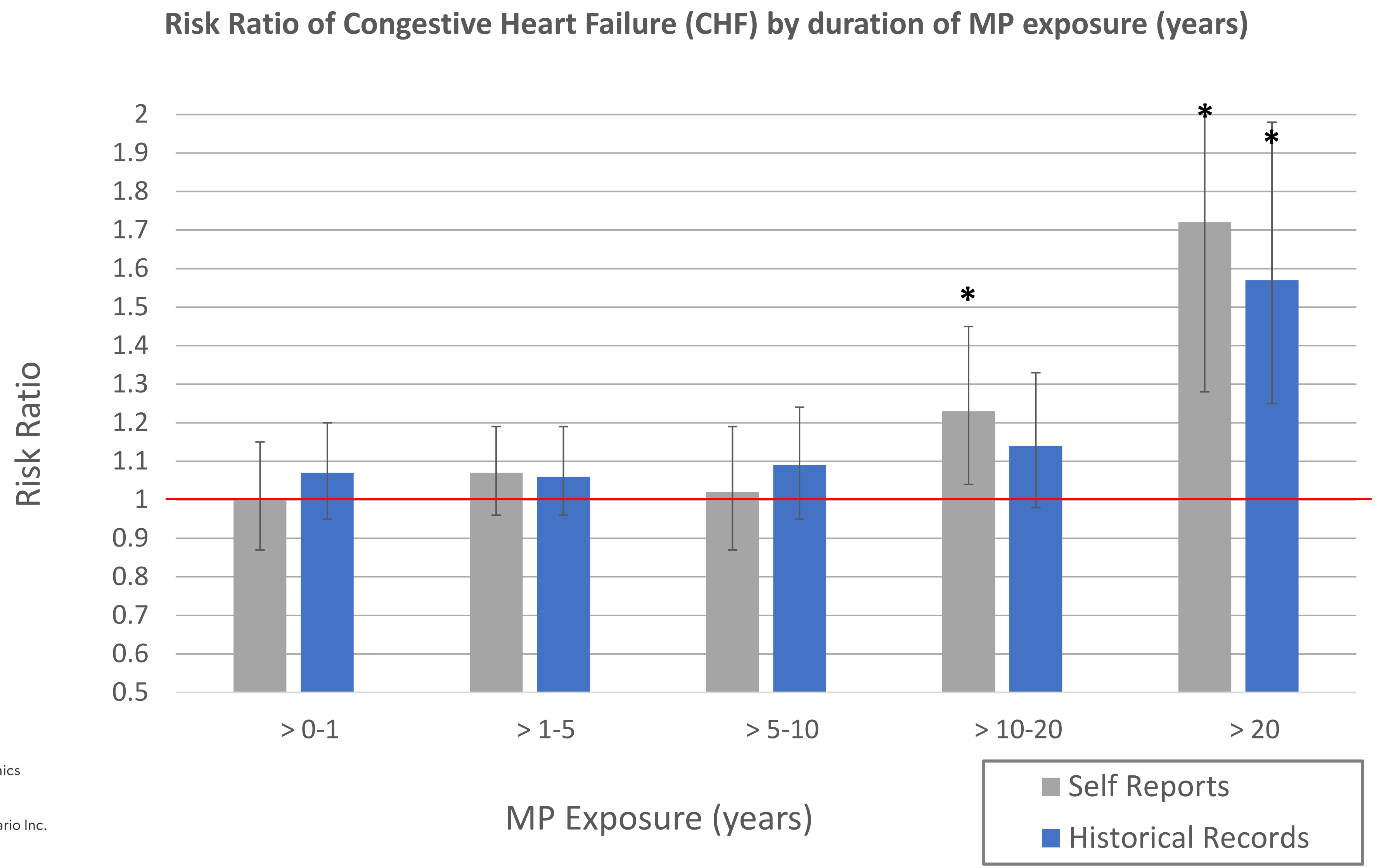

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Conclusions

- MP-exposed compared to never exposed had a **~10%** increased risk of IHD, AMI, and CHF
- Mine workers with **10-20 years of MP exposure** had a **20-30%** increased risk of AMI and a **14-23%** increased risk of CHF (depending on the exposure assessment approach)
- Mine workers with **greater than 20 years of MP exposure** had a 50-60% increased risk AMI and a 60-70% increased risk of CHF (depending on the exposure assessment approach)
- The increased rates of IHD, AMI, and CHF appeared to increase with the duration of exposure

Questions?

CROSH
CRSST
centre for research in occupational safety and health at Laurentian University
centre de recherche sur la santé et sécurité au travail à l'Université Laurentienne

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Occupational Cancer Research Centre