PURDUE UNIVERSITY

Exposure Assessment and Real-Time Evaluation of Road Surface Planer Dust Control Technology for Highway Construction Applications

Beauregard Middaugh, M.S.
School of Health Sciences
Bryan Hubbard, Ph.D., P.E. (PI)
Department of Building Construction Management
Neil Zimmerman, Ph.D.
School of Health Sciences
James McGlothlin, MPH, Ph.D., CPE
School of Health Sciences

Outline

- Introduction
- Specific Aims
- Background
- Materials and Methods
- Results
- Discussion
- Conclusions

Cold-Planer Equipment Utility

Specific Aims

- The purpose of this research study was to:
- 1) evaluate respirable dust and quartz exposure during asphalt milling with a typical cold-planer, heavy equipment utility.
- 2) determine if a gravity-fed water supply system, primarily used to extend grinder lifetime, is an effective means of reducing exposure for the operator.
- 3) assess the magnitude of exposure variation attributed to outdoor wind conditions.

Construction

- 111 million workers employed in the construction industry worldwide.
- Construction leads all industries in U.S. with highest percentage of silicosis related deaths.
- 4 million miles of government roadways in U.S.
- 14 % of roadways are currently in need of repair.
- Cold-planers are frequently used during systematic patching and repair of roadway and parking lot systems.

(International Labour Organization, 2001; NIOSH, 2003; U.S. Federal Highway Administration (FHWA), 2006; Valiante, Schill, Rosenman, & Socie, 2004; Linch, 2002; NIOSH, 2004)

Health Relevance

- Thousands of silica-related deaths still occur every year worldwide.
- Lung Cancer
  - Quartz (i.e. crystalline silica) is an IARC Group I, known human carcinogen.
- Chronic silicosis
  - Associated with long-term inhalation of respirable silica particles.
  - Untreatable progressive lung fibrosis.
  - The risk of developing radiographic silicosis over a 45 year working lifetime at a silica concentration near 0.1 mg/m^3 may be as high as 47 to 90 percent.
- The current 8-Hour TWA ACGIH TLV's
  - Respirable dust (3 mg/m^3)
  - Quartz (0.025 mg/m^3).

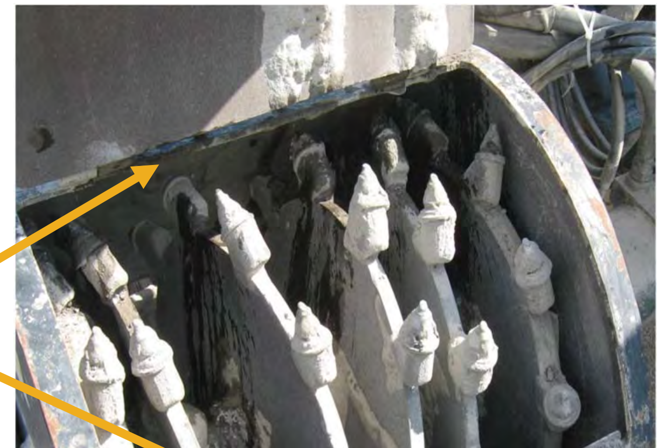
(World Health Organization (WHO), 2000; IARC, 1997; NIOSH, 2004; NIOSH, 2002; Greaves, 2000; Steenland, 2005; ACGIH, 2009)

General Study Design

- 2 day study.
- 1 highway construction site.
- 2 volunteer equipment operators.
- 65-95 minute air monitoring periods.
- 4 monitoring periods without dust control and 4 monitoring periods with wet dust control.
- Exposure control methods were rotated after every monitoring period.

Wet Control Method

- Gravity-fed water supply system.
- 25 gallon water tank.
- 6 nozzle spray bar system located above the cutting bits.
- Estimated system flow rate of 0.39 gallons/minute.
- Estimated system water pressure of 2.4 PSI.



Filter Air Monitoring

Task-Based Side-By-Side Personal Filter Sampling

- Traditional Pump
  - Respirable Dust and Crystalline Silica.
  - Aluminum Cyclone
  - Calibrated at 2.5 LPM.
  - 5 µm pore size, pre-weighed polyvinyl chloride (PVC) filters, loaded in three-piece 37 mm cassettes
  - Analyzed gravimetrically via the NIOSH 0600 method.
  - Analyzed using x-ray diffraction spectrometry via the NIOSH 7500 method.

- DustTrak II 8530 (2)
  - Respirable Dust and Crystalline Silica.
  - Dorr-Oliver Cyclone
  - Calibrated at 1.7 LPM.
  - 5 µm pore size, pre-weighed polyvinyl chloride (PVC) filters, loaded in two-piece 37 mm cassettes
  - Analyzed gravimetrically via the NIOSH 0600 method.
  - Analyzed using x-ray diffraction spectrometry via the NIOSH 7500 method.


Real-Time Air Monitoring

Task-Based Side-By-Side Personal Real-Time Sampling

- DustTrak 8520(1)
  - Respirable Dust.
  - Dorr-Oliver Cyclone.
  - Calibrated at 1.7 LPM.
  - Logged every second.

- DustTrak II 8530(2)
  - Respirable Dust.
  - Dorr-Oliver Cyclone.
  - Calibrated at 1.7 LPM.
  - Logged every second.

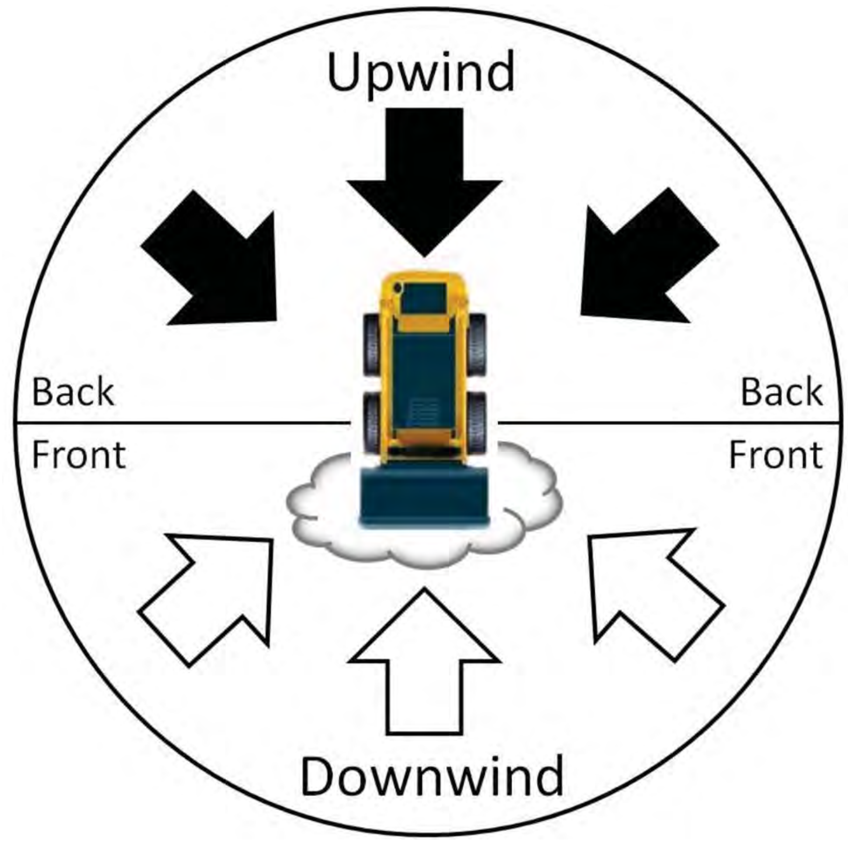
Real-time Worker Heading

Video Monitoring

Aerial Map of Worksite

Real-time Wind Conditions

- Kestrel Weather Station.
  - Real-time onsite wind conditions.
- Relative wind condition.
  - Combine heading and wind direction.
  - Worker upwind or downwind of dust source.
- Real-time exposure measurements.
  - Matched with the relative wind condition.



Filter Sample Results

			Concentration (mg/m^3)				Concentration (mg/m^3)			
ID[A]	Control Method	Sample Method[B]	RSP Dust	GM (GSD)	Median	Est. 8-Hr. TWA[D]	Quartz	GM (GSD)	Median	Est. 8-Hr. TWA[D]
1	None	1	0.29[C]	0.44(1.61)	0.47	0.31	0.030[C]	0.026(1.072)	0.026	0.017
3	None	1	0.26[C]				0.026[C]			
5	None	1	0.76				0.025[C]			
7	None	1	0.64				0.026[C]			
1	None	2	0.46[C]	0.44(1.59)	0.41	0.27	0.046[C]	0.035(1.240)	0.037	0.025
3	None	2	0.37[C]				0.037[C]			
5	None	2	0.25[C]				0.025[C]			
7	None	2	0.89				0.037[C]			
2	Wet	1	0.25[C]	0.50(2.07)	0.57	0.38	0.025[C]	0.023(1.078)	0.024	0.016
4	Wet	1	0.25[C]				0.025[C]			
6	Wet	1	0.90				0.024[C]			
8	Wet	1	1.20				0.021[C]			
2	Wet	2	7.50	0.74(3.80)	0.36	0.24	0.036[C]	0.035(1.063)	0.036	0.024
4	Wet	2	0.37[C]				0.037[C]			
6	Wet	2	0.35[C]				0.035[C]			
8	Wet	2	0.32[C]				0.032[C]			

[A]The ID number refers to the monitoring period it was collected.

[B]Sample method (1) refers to the traditional sampling train (i.e. sampling pump and aluminum cyclone) and method (2) refers to the DustTrak II 8530 (DT2) sampling train.

[C]One-half the LOD was substituted for the concentrations below the LOD (Hornung & Reed, 1990).

[D]*Est. 8-Hr. TWA=(Task-Based Median Concentration X 180 minutes)/480 minutes.*

Real-Time Sample Results

				RSP Dust Concentration (mg/m^3)					
ID[A]	Control Method	Sample Method[B]	N	GM (GSD)	Median	Max	Grand Median[C]	Median Peak[D]	% Dust Reduction[E]
1	None	1	3928	0.11(3.73)	0.08	28.6	0.11	44.2	-
3	None	1	4825	0.07(3.25)	0.05	12.7			
5	None	1	4772	0.13(5.60)	0.06	59.8			
7	None	1	4677	0.18(7.44)	0.12	79.7			
1	None	2	3928	0.18(3.63)	0.12	32.2	0.18	30.9	-
3	None	2	4825	0.08(2.67)	0.06	9.43			
5	None	2	4772	0.16(5.12)	0.08	56.6			
7	None	2	4677	0.20(5.83)	0.12	29.5			
2	Wet	1	4914	0.09(4.70)	0.05	27.6	0.09	49.6	18.2
4	Wet	1	4826	0.11(3.85)	0.08	52.5			
6	Wet	1	4977	0.13(6.92)	0.06	65.3			
8	Wet	1	5701	0.17(6.89)	0.12	46.7			
2	Wet	2	4914	0.12(4.03)	0.07	34.5	0.12	35.9	33.3
4	Wet	2	4826	0.14(3.24)	0.11	37.3			
6	Wet	2	4977	0.17(5.88)	0.08	68.7			
8	Wet	2	5701	0.21(5.75)	0.15	27.9			

[A]The ID number refers to the monitoring period it was collected.
[B]Sample method (1) refers to the DustTrak 8520 (DT1) and method (2) refers to the DustTrak II 8530 (DT2).
[C]Median of the geometric mean sample concentrations.
[D]Median of the maximum sample concentrations.
[E]*% Dust Reduction= (Grand Median RSP Dust Concentration without Dust Control-Grand Median RSP Dust Concentration with Wet Control)/Grand Median RSP Dust Concentration without Dust Control X 100.*

Real-Time Wind Results

			Downwind (mg/m³)			Wind	Upwind (mg/m³)			Wind
ID[A]	Control Method	Sample Method[B]	N[D]	GM (GSD)	Max	Velocity (m/s)[C]	N[D]	GM (GSD)	Max	Velocity (m/s)[C]
1	None	1	363	0.23(3.63)	28.6	2.0	292	0.07(2.80)	19.6	1.8
3	None	1	314	0.08(3.23)	4.97	4.2	267	0.10(3.67)	5.27	3.2
5	None	1	216	1.29(3.51)	43.3	2.7	387	0.11(3.41)	12.9	2.7
7	None	1	69	0.77(2.92)	9.06	4.2	297	0.05(2.83)	1.15	4.3
1	None	2	363	0.38(3.47)	32.2	2.0	292	0.10(2.50)	8.97	1.8
3	None	2	314	0.09(2.88)	7.22	4.2	267	0.11(2.97)	9.43	3.2
5	None	2	216	1.56(3.21)	51.6	2.7	387	0.12(3.00)	15.7	2.7
7	None	2	69	0.80(3.15)	16.1	4.2	297	0.07(2.17)	0.80	4.3
2	Wet	1	416	0.22(5.46)	25.3	2.3	362	0.06(2.94)	8.24	2.0
4	Wet	1	467	0.23(3.54)	28.7	4.0	196	0.07(1.81)	0.60	4.5
6	Wet	1	207	1.12(3.26)	26.1	4.1	236	0.05(2.78)	9.02	3.9
8	Wet	1	226	0.73(4.24)	18.8	4.1	334	0.06(3.44)	13.8	4.2
2	Wet	2	416	0.26(4.67)	26.5	2.3	362	0.08(2.82)	13.5	2.0
4	Wet	2	467	0.25(3.11)	21.9	4.0	196	0.07(1.81)	0.48	4.5
6	Wet	2	207	1.12(3.26)	27.7	4.1	236	0.07(2.52)	5.00	3.9
8	Wet	2	226	0.78(3.91)	15.4	4.1	334	0.08(2.97)	10.2	4.2

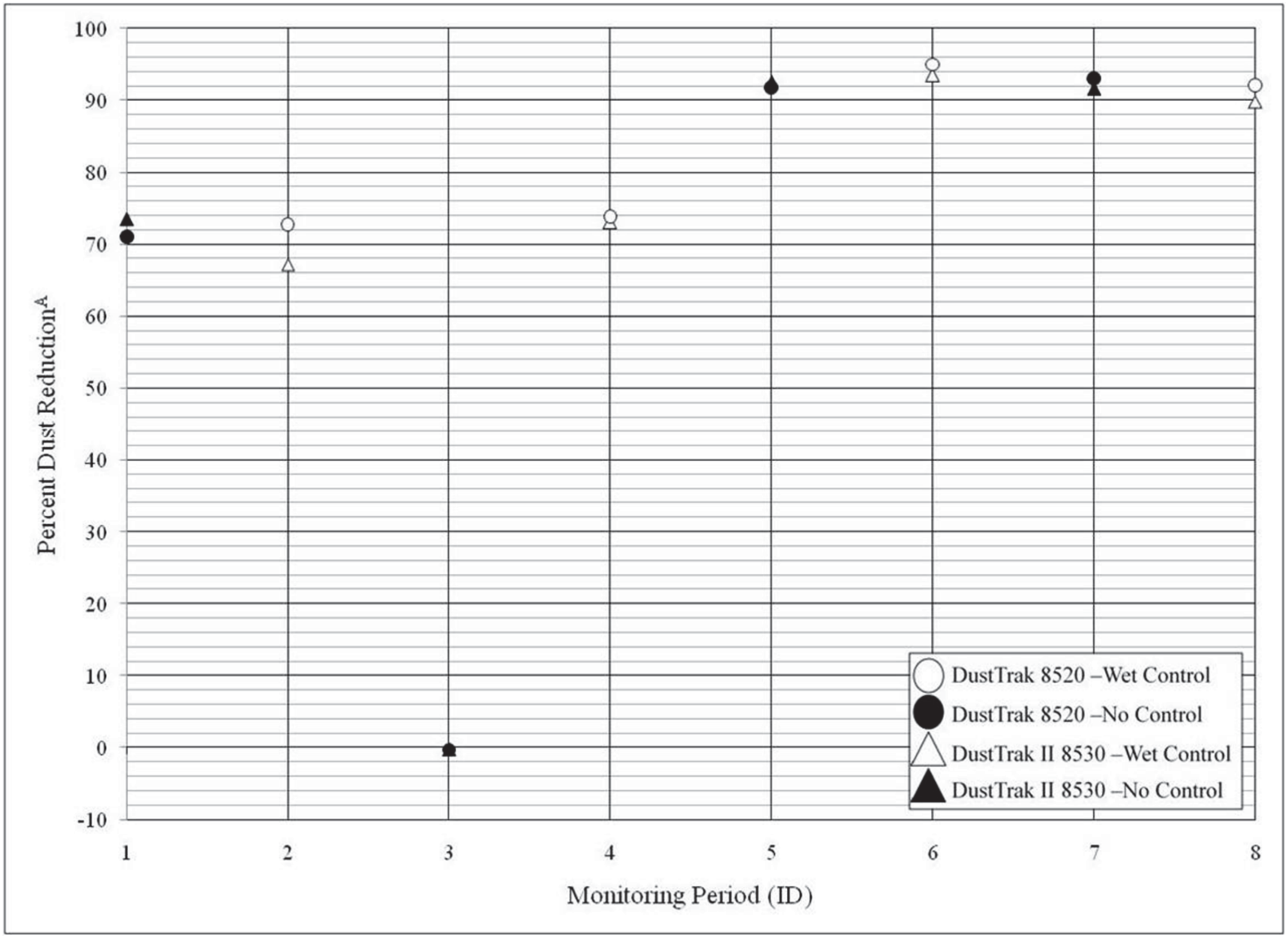
[A]The ID number refers to the monitoring period it was collected.

[B]Sample method (1) refers to the DustTrak 8520 and method (2) refers to the DustTrak II 8530.

[C]Wind velocity (m/s) is the average wind speed for the corresponding wind condition.

[D]N refers to the total number of individual measurements collected per wind condition (i.e. downwind or upwind) with a detectable wind velocity.

Upwind vs. Downwind Exposure



[A] *Percent Dust Reduction=(GM Dust Conc. when Downwind – GM Dust Conc. when Upwind)/GM Dust Conc. when Downwind X 100.*

Discussion

- The operator’s estimated 8-hour TWA for 3 hours of respirable dust and quartz exposure is below each respective TLV with and without exposure control.
- The operator’s downwind exposure was also significantly higher than upwind exposure ($p<0.01$) (2-sided Wilcoxon).
- An average percent reduction of 80.0 percent was seen for upwind exposure compared to downwind exposure.
- Therefore, a substantial amount of dust reduction bias could be introduced if wind conditions are not accurately assessed during an outdoor field study.

Conclusions

- Exposure Control for Operator.
  - Closed-cab on skid loader.
- Exposure Control for Adjacent Workers.
  - The flow rate of the water system could feasibly be increased to 1.5 gallons/minute (3.8 X current flow rate) by utilizing a water pump and increasing the water tank volume to 50 gallons.
  - Working upwind of the exposure can also be an effective supplemental control.

Future Research Needed

- Evaluation of improved water supply system in a laboratory setting.
- Development of easier methods for tracking real-time worker heading for wind condition identification in field studies.
- Field assessments are still needed for other dust-producing roadway operations and control technologies.

Acknowledgements

- This research study was supported by the participating contractor, E & B Paving, Inc. and the NIOSH and the Pilot Research Project Training Program of the University of Cincinnati Education and Research Center Grant #T42/OH008432-05.

Works Cited

- **American Conference of Governmental Industrial Hygienists (ACGIH):** *Threshold Limit Values and Biological Exposure Indices*. pp 51, 76-77. Cincinnati, OH.: ACGIH, 2009.
- **Greaves, I:** Not-So-Simple Silicosis: A Case for Public Health Concern. *American Journal of Industrial Medicine* 37:245-251 (2000).
- **Hornung, R., L. Reed:** Estimation of Average Concentration in the Presence of Nondetectable Values. *Journal of Applied Occupational and Environmental Hygiene* 5:46-51 (1990).
- **International Agency for Research on Cancer (IARC):** IARC Monographs on the Evaluation of the Carcinogenic Risks to Humans: Silica Vol 68. IARC, 1997.
- **International Labour Organization**.: The Construction Industry in the Twenty-First Century: Its Image, Employment Prospects, and Skill Requirements. *TMCIT-R-2001-07-0141-4.Doc/v1* (pp. 1-71). Geneva: International Labour Office: 2001.
- **Linch, K.** Respirable Concrete Dust - Silicosis Hazard in the Construction Industry. *Applied Occupational and Environmental Hygiene* , *17*, 209-221 (2002).
- **National Institute for Occupational Safety and Health (NIOSH):** *Hazard Review: Health Effects of Occupational Exposure to Respirable Crystalline Silica.* Cincinnati, OH.: NIOSH, 2002.
- **National Institute for Occupational Safety and Health (NIOSH):** *Methods 0500, 0600, and 7500 NIOSH Manual of Analytical Methods (NMAM).* Washington, D.C.: NIOSH, 1998.
- **National Institute for Occupational Safety and Health (NIOSH) :** *Results of a Pilot Study of Dust Control Technology for Asphalt Milling.* Cincinnati, OH: U.S. Department of Health and Human Services :2004.
- **Steenland, K.:** One Agent, Many Diseases: Exposure-Response Data and Comparative Risks of Different Outcomes Following Silica Exposure. *American Journal of Industrial Medicine* 48:16-23 (2005).
- **U.S. Federal Highway Administration (FHWA):** (2006, March 9). *Status of the Nation's Highways, Bridges, and Transit: 2004 Conditions and Performance*. Retrieved August 9, 2010, from Description of Current System: http://www.fhwa.dot.gov/policy/2004cpr/part1.htm
- **Valiante, D., Schill, D., Rosenman, K., & Socie, E.**: Highway Repair: A New Silicosis Threat. *American Journal of Public Health* , *84*, 876-880. (2004).
- **World Health Organization (WHO):** (2000, May). *Protection of the Human Environment*. Retrieved August 7, 2010, from Silicosis: http://www.who.int/peh/Occupational_health/OCHweb/OSHpages/OSHDocuments/Factsheets/Silicosis.htm

Questions?

University of Cincinnati
11th Annual
Pilot Research Project
Symposium
October 14-15, 2010

Main Menu

Hosted by: The University of Cincinnati Education and Research Center Supported by:
The National Institute for Occupational Safety and Health.
(NIOSH) Grant #: T42/OH008432-05

Produced by Kurt Roberts Department of Environmental Health
Copyright 2010, University of Cincinnati