CDC Workplace Safety and Health

Evaluation of Employees' Chemical Exposures While Blending and Repackaging Glass Beads for Road Markings

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Health Hazard Evaluation Report
HETA 2008-0017-3095
Weissker Manufacturing
Palestine, Texas
November 2009

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
NIOSH National Institute for Occupational Safety and Health

The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

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ABBREVIATIONS

µg	Microgram
µm	Micrometer
ACGIH®	American Conference of Governmental Industrial Hygienists
CFR	Code of Federal Regulations
GA	General area
GC-MS	Gas chromatography-mass spectrometry
HHE	Health hazard evaluation
LOD	Limit of detection
LOQ	Limit of quantitation
Lpm	Liters per minute
MSDS	Material safety data sheet
mg/m^3	Milligrams per cubic meter
mm	Millimeter
MDC	Minimum detectable concentration
MQC	Minimum quantifiable concentration
NAICS	North American Industry Classification System
ND	Not detected
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PBZ	Personal breathing zone
PEL	Permissible exposure limit
PPE	Personal protective equipment
ppm	Parts per million
REL	Recommended exposure limit
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
VOC	Volatile organic compound
WEEL	Workplace environmental exposure level

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation at Weissker Manufacturing in Palestine, Texas. The requestors were concerned about exposure to lead, arsenic, formaldehyde, and dust while handling reflective glass beads used for road markings. NIOSH investigators conducted an evaluation in January 2008.

What NIOSH Did

- We observed the glass bead blending and repackaging process.
- We took personal breathing zone and general area air samples for elements, respirable and total dust, silica, and formaldehyde.
- We took wipe samples from employees' hands, work surfaces, and the lunchroom table and analyzed them for elements.
- We had bulk samples of glass beads analyzed for elements, volatile organic compounds, and particle size.
- We reviewed the material safety data sheets for the glass beads.
- We talked to employees about their work and health.

What NIOSH Found

- Weissker received glass beads with chemical coatings from Russia and China.
- Employee complaints were associated with the glass beads imported from China, which had a coating that contained amines.
- All air samples results were below applicable occupational exposure limits.
- We found low levels of elements on employees' hands, the lunchroom table, and work surfaces sampled.
- The glass beads contained very low concentrations of elements, no detectable volatile organic compounds, and were too large to be inhaled into the lungs.
- We saw employees wearing filtering facepiece respirators but not safety glasses.
- Due to employees' health concerns, Weissker informed us that they are no longer ordering glass beads from China.
- Prior to our site visit an employee was injured while transferring glass beads from a Super Sack to a metal bin when the Super Sack fell, pinning the employee's arm against the bin.

What Managers Can Do

- Require employees to wear safety glasses or goggles when handling glass beads.
- Instruct employees to position the bottom of the Super Sack below the top rim of the hopper before cutting and draining the glass beads.

What Employees Can Do

- Wear safety glasses or goggles when handling glass beads.
- Wash your hands before eating or touching your face.
- Report work-related health and safety concerns to your supervisor.
- Do not place your arms between the bottom of the Super Sack and the metal bin while transferring glass beads.

Summary

On October 16, 2007, NIOSH received a confidential employee request for an HHE at Weissker Manufacturing (Weissker) in Palestine, Texas. Employees were concerned about exposures to lead, arsenic, formaldehyde, and dust while handling reflective glass beads. Health problems listed on the request and attributed to the dust from the glass beads included glassy eyes, sore throat, body aches, and flu-like symptoms. Weissker imported the glass beads in Super Sack® containers (2200-pound capacity fabric bags) from Russia and China and repackaged the beads for resale. Both the Chinese and Russian glass beads had a silane coating. Employees complained about a fish-like odor emitted from the Chinese beads when they were wet. The odor may have come from the amines in the glass beads' coating. Weissker is no longer purchasing beads from China due to employees' health concerns. At the time of this evaluation six employees at Weissker worked one 8-hour shift.

NIOSH investigators evaluated dust and chemical exposures from blending and repackaging glass beads. Results of air samples for dust, elements, silica, and formaldehyde were below applicable occupational exposure limits. Wipe samples from work surfaces and employees' hands contained very low levels of elements. We recommend that employees wear eye protection when handling the glass beads and that they wash their hands before eating or touching their face.

During our site visit on January 22–24, 2008, we observed the blending and repackaging process, reviewed the MSDSs for the glass beads, and interviewed employees. We also collected PBZ air samples for respirable dust, crystalline silica, elements (including arsenic and lead), and formaldehyde and GA air samples for total dust, formaldehyde, and elements. We analyzed bulk samples of glass beads for elements, VOCs, and size. We took wipe samples from employees' hands and work surfaces and had them analyzed for elements. Our review of the OSHA 300 Logs of Work-Related Injuries and Illnesses revealed that an employee was injured in June 2007, when his arm was trapped between a metal bin and a Super Sack while he was emptying it.

All air sampling results were below applicable OELs. No VOCs were detected in the bulk samples of glass beads. Elements were either not detected or were detected at very low concentrations. Particle size analysis of the glass beads revealed that they were too large to be deposited in the respiratory tract or the lungs. We measured very low levels of elements on employees' hands, on work surfaces, and on the lunchroom table. We conducted confidential medical interviews with five employees; some reported eye and throat irritation.

We recommend that employees wear safety glasses or goggles to prevent glass beads from getting in their eyes and that they wash their hands before eating or touching their face. We also recommend that employees not place their arms underneath the Super Sack containers when they are being emptied to prevent hand and arm injuries.

Keywords: NAICS 327215 (Glass Product Manufacturing Made of Purchased Glass), retroreflective glass beads, VOCs, formaldehyde, elements, respirable dust, upper respiratory irritation, eye irritation

Introduction

On October 23, 2007, NIOSH received a confidential employee request for an HHE at Weissker Manufacturing (Weissker), in Palestine, Texas. The requestors were concerned about exposure to lead, arsenic, formaldehyde, and dust while handling reflective glass beads. Specific health effects included glassy eyes, sore throat, body aches, and flu-like symptoms. Maintenance employees, baggers, loaders, and a supervisor were listed as potentially exposed employees.

Background

Weissker is an independent supplier of glass beads for road markings. At the time of this evaluation the company received glass beads of different diameters from China and Russia in large Super Sack® containers (2,200-pound capacity fabric bags). Currently the company is only importing glass beads from Russia. Employees blend and repackage the beads in smaller paper sacks or boxes for distribution to state transportation departments and other customers. The glass beads are applied over wet paint sprayed on road surfaces to make street markings reflective to automobile headlights. The beads vary in size from 0.2–1.2 mm and have a silane coating.

The repackaging process begins with lifting a Super Sack with a forklift over a metal bin, then cutting the bottom of the container with a knife to empty the beads into the bin (Figure 1).

Figure 1. Employee emptying a Super Sack® into a bin

Background (continued)

The metal bin is lifted by a forklift, and the glass beads are poured into hoppers. From the hoppers the beads are gravity fed into smaller cardboard boxes or paper sacks that are shipped to customers (Figure 2).

Figure 2. Filling a shipping box with glass beads.

Six Weissker employees worked an 8-hour shift at the time of this evaluation. Weissker management provided employees safety glasses, foot protection, leather gloves, and a NIOSH-approved 3M model 8210 N95 filtering-facepiece respirator. Weissker required employees to wear respirators because of potential dust exposure from handling the glass beads. During this evaluation we observed all employees (with the exception of the supervisor) wearing filtering-facepiece respirators. None of the employees wore safety glasses or gloves.

Assessment

During the January 22–24, 2008, site visit we evaluated employees' exposures to dust, elements, and formaldehyde while blending and repackaging glass beads. During the visit we held opening and closing meetings; interviewed employees; toured the facility; and collected air, surface, and bulk samples for potential workplace contaminants.

On January 22, 2008, we conducted confidential interviews with five employees, inquiring about symptoms they believed were related to workplace exposures and any concerns they had about workplace exposures while handling the glass beads.

On January 23 and 24, 2008, we collected 15 full-shift PBZ air samples for 31 elements (which included lead and arsenic), six for formaldehyde, and three for respirable dust and crystalline silica. We also collected three GA air samples for elements, four for formaldehyde, and four for total dust. We obtained 12 wipe samples from employees' hands before they started their work shift and at the end of their work shift before they washed their hands. We also collected surface wipe samples from the lunchroom table, laboratory counter, adding machine, microwave top, and conference room table. The wipe samples were analyzed for 23 elements, which included lead and arsenic.

We collected six bulk samples of glass beads (three each from Russia and China) and had them analyzed for elements. We submitted three samples of Chinese beads for VOC analysis and two samples of Chinese beads and one of Russian beads for particle size analysis. We obtained samples of Russian glass beads from Weissker and a sample of the silane coating applied to these glass beads (3-methacryloxypropyltrimethoxysilane) from Dow Chemical and submitted them for qualitative identification of VOCs by GC-MS. The silane product from Dow Chemical was used to obtain a GC-MS spectrum for comparison with the GC-MS analysis of the glass beads. Headspace samples were collected using three-bed thermal desorption tubes at ambient temperature above dry glass beads and also above glass beads in water. To evaluate any potential corrosive hazards to employees' skin, the glass beads were placed in tap water and the pH of the solution was checked using test strips. Appendix A includes additional information on the methods used in this evaluation.

Results

Air Samples

Full-shift PBZ air sample results for respirable dust are provided in Table 1. GA air sample results for total dust are provided in Table 2. Air sample results for formaldehyde are provided in Table 3. Concentrations of respirable dust ranged from 0.05–0.18 mg/m^3, and total dust ranged from ND–0.15 mg/m^3; both were

Results (continued)

much lower than their OSHA PEL-TWAs of 5 mg/m^3 (respirable dust) and 15 mg/m^3 (total dust) [29 CFR Part 1910.1000] for particulates not otherwise regulated. Silica was not detected in the respirable dust PBZ air samples (MDC was 0.01 mg/m^3 based on a sample volume of 797 liters). All formaldehyde concentrations were below the NIOSH REL of 0.016 ppm for up to a 10-hour TWA exposure [NIOSH 2005]. Full-shift PBZ air sampling results for elements were well below applicable occupational exposure limits. More detailed information about the OELs and health effects of elements, formaldehyde, respirable and total dust, and VOCs is provided in Appendix B.

Table 1. PBZ air sampling results for respirable dust

Sample Date	Job Title	Sample Time (minutes)	Sample Volume (liters)	Concentration (mg/m^3)
01/23/08	Packer/Forklift Operator	455	797	Trace
01/23/08	Warehouseman	456	785	0.18
01/23/08	Bagger/Forklift Operator	455	773	Trace
01/24/08	Warehouseman	364	642	Trace
01/24/08	Lab Technician	412	722	Trace
01/24/08	Packer	412	700	Trace
OSHA PEL-TWA				5
ACGIH TLV-TWA				3
Minimum detectable concentration (MDC)				0.040
Minimum quantifiable concentration (MQC)				0.13

The MDC and MQC were calculated by dividing the method LOD and LOQ by the average sample volume.
Trace = concentration is between the MDC and the MQC

Table 2. GA air sampling results for total dust

Sample Date	Sample Location	Sample Time (minutes)	Sample Volume (liters)	Concentration (mg/m^3)
01/23/08	Bagging Station	440	887	0.30
01/23/08	Laboratory	437	864	ND
01/24/08	Bagging Station	441	896	0.15
01/24/08	Laboratory	441	864	Trace
OSHA PEL-TWA				15
ACGIH TLV-TWA				10
Minimum detectable concentration (MDC)				0.034
Minimum quantifiable concentration (MQC)				0.10

ND = not detected, the concentration is below the MDC

Trace = concentration is between the MDC and the MQC

Table 3. PBZ air sampling results for formaldehyde

Sample Date	Job Title/Location	Sample Time (minutes)	Sample Volume (Liters)	Concentration (ppm)
01/23/08	Packer/Forklift Operator	456	13.0	0.0073
	Warehouseman	457	13.1	0.0090
	Bagger/Forklift Operator	455	13.0	Trace
	Manager	455	13.0	0.0065
	Lab Technician	450	12.9	0.0073
	Packer	445	12.7	Trace
	Outdoor	446	12.8	ND
	Conference Room	443	12.7	0.0098
	Bagging Machine	449	12.8	Trace
	Laboratory	437	12.5	Trace
NIOSH REL-TWA				0.016
OSHA PEL-TWA				0.75
Minimum detectable concentration (MDC)				0.0019
Minimum quantifiable concentration (MQC)				0.0055

ND = not detected, the concentration is below the MDC
Trace = concentration is between the MDC and the MQC

Wipe Samples

Tables 4 and 5 summarize the wipe sample results for arsenic, cadmium, chromium, copper, lead, manganese, and nickel. These elements were selected from a total of 30 elements because of their potential toxicity and because they were present above the LOD. Hand wipe samples were collected from employees at the beginning and at the end of their work shift. The mean postshift amounts of arsenic, cadmium, chromium, copper, lead, and manganese on the hand wipe samples were statistically significantly higher than the preshift amounts. While not statistically significant, the average amount of nickel also increased over the work shift. The hand wipe sample results were highest on the laboratory technician and a packer/forklift operator. One employee reported being a cigarette smoker, but this employee's sample results were generally lower than other employees' results. The highest level of elements on work surfaces was on an adding machine used by the laboratory technician. The higher level of elements detected on the laboratory technician's hands may be due to oxidation of the paint on the adding machine and the surface of the metal trays used for quality control evaluation of the glass beads.

Table 4. Summary of hand wipe results

Element	Results* (µg/sample)						
	Before Shift (n=6)			After Shift (n=6)			
	Min	Max	Avg	Min	Max	Avg	*P* value†
Arsenic	ND	ND	ND	ND	9.1	6.5	0.0081‡
Cadmium	ND	0.26	0.15	0.41	1.3	0.63	0.031§
Chromium	0.24	0.97	0.55	1.9	4.9	3.3	0.0029‡
Copper	5.0	18	10	11	490	110	0.031§
Lead	0.63	2.6	1.4	4.3	14	8.2	0.0068‡
Manganese	0.37	1.5	0.97	6.0	26	11	0.031§
Nickel	1.0	7.2	2.6	2.1	4.9	3.5	0.33‡

* Results were blank corrected (the concentration of the metal found in unused wipes was subtracted from the results).
ND = not detected
† A *P* value of <0.05 indicates a statistically significant increase in the amount of the element detected on the wipe sample over the work shift.
‡ *P* value was determined using a paired *t*-test.
§ *P* value was determined using a paired sign test.
When a result was reported by the laboratory as ND, the limit of detection (3 µg/sample for arsenic, and 0.06 µg/sample for cadmium) was divided by √2, and the result was used in calculations to determine the average mass per sample.

Table 5. Summary of surface wipe results

Element	Result* (µg/100 square centimeters)					LOD	LOQ
	Adding Machine	Lab Counter	Lunchroom Table	Microwave	Conference Table		
Arsenic	ND	ND	ND	ND	ND	3	9.3
Cadmium	(0.16)†	ND	ND	ND	ND	0.06	0.18
Chromium	0.91	1.0	ND	ND	(0.24)	0.1	0.34
Copper	44	2.9	0.60	(0.16)	0.88	0.1	0.46
Lead	(3.8)	ND	ND	ND	ND	0.5	10
Manganese	3.9	(0.16)	0.57	ND	(0.22)	0.1	0.46
Nickel	(0.31)	(0.43)	ND	ND	ND	0.2	0.73

* Results were blank corrected (the concentration of the metal found in unused wipes was subtracted from the results).
ND = not detected
† Results with parentheses were between the LOD and the LOQ.

Glass Beads Bulk Samples

Three bulk samples of glass beads were submitted for qualitative analysis of VOCs. No peaks indicative of VOCs, other than those observed from blank samples or system backgrounds, were detected in any of the samples; no VOCs were detected above background levels.

Six bulk samples of glass beads were digested and analyzed for elements per NIOSH Method 7303. Sample results were reported in units of milligrams per kilogram. Most elements were not detected, but a few were detected at levels between the LOD and LOQ. Calcium, copper, cobalt, barium, and strontium were detected above the LOQ but at very low concentrations. When a sample of glass beads was placed in tap water, the pH of the tap water did not change. Two Chinese and two Russian bulk samples of glass beads were submitted for shape and particle size analysis by scanning electron microscopy. The particle size analysis revealed that the glass beads were not of a respirable size. That was also confirmed by low concentrations of respirable dust in PBZ air samples. Table 6 provides the results for the particle size analysis and morphology.

Table 6. Glass beads particle sizes

Bead Source	Bead Size, in mm (n=4)			Comments
	Min	Max	Avg	
China	0.5	1.0	0.7	Elongated particles and agglomerates of 2–3 particles
China	0.2	8.3	0.7	Individual spheres and some agglomerates
Russia	—	—	1.0*	Individual spheres
Russia	—	—	1.2*	Individual spheres

* The laboratory provided only the average size for these samples

During our tour of the facility we noted that labeling on the Super Sacks indicated that the glass beads had a silane coating to improve adhesion. The coating on the Chinese glass beads contained 0.15% silane, while the Russian glass beads had a coating that contained no more than 0.008% silane. The coating on the Chinese glass contained 0.15% (r-Aminopropyl) triethoxy silane.

The Russian glass beads' coating contained a maximum of 0.008% methacryloxypropyltrimethoxysilane and 0.02% silicon dioxide. To evaluate whether the silane coating on the Russian glass beads was released during handling and processing and if this coating was a potential source of VOCs, three bulk samples of the glass beads were extracted with methanol and analyzed by GC-MS. Neither VOCs nor methacryloxypropyltrimethoxysilane was identified by GC-MS. No VOCs were detected when the glass beads were heated to 50°C. When heated to 300°C, traces of methacrylic acid, acetic acid, acrolein, and acetone were detected. We only performed these tests on the Russian glass beads because Weiskker is no longer buying Chinese glass beads due to employees' concerns about health hazards associated with these beads. One of the HHE requestors mentioned a foul odor associated with wet glass beads. This odor may have been from amines (some of which have a fish-like odor) in the silane coating on the Chinese glass beads.

Interviews

We interviewed five Weissker employees. Their ages ranged from 22 to 48 years. Time of employment ranged from 4 months to 2 years. Their job duties included filling bags and cartons with glass beads, sealing them, loading pallets and trailers, operating a forklift, emptying bags, operating the auger and the bag closer, sweeping, and performing quality control. Employees reported using PPE such as steel-toe footwear, eye protection, and gloves, but not consistently or continually throughout the work shift. We did not observe employees wearing eye protection or gloves during this evaluation.

All interviewed employees agreed that dust was a problem during work, especially when emptying Super Sack containers and filling bags. One employee noted occasionally feeling glass beads in the mouth. Most employees also agreed that the glass beads would occasionally have an odor that was apparent when the glass beads appeared to be wet. Employees reported a variety of eye and upper respiratory irritation symptoms, such as dry eyes and throat.

Other

Employees were required to wear NIOSH-approved 3M model 8210 N95 filtering-facepiece respirators when handling glass beads. With the exception of the supervisor, all employees were wearing respirators during the 2 days of this evaluation. However, the company did not have air sampling data or other documentation of a hazard that would require the use of respiratory protection.

Results (continued)

The company also did not have a written respiratory protection program outlining procedures for medical evaluation, fit testing, and training that met the requirements of the OSHA respiratory protection standard [29 CFR Part 1910.134].

We observed an employee draining a Super Sack into a metal bin by reaching over the bin to cut holes in the bottom of the sack with a knife. While this was the routine method used to drain the Super Sacks, it had previously resulted in an employee being injured when a Super Sack fell off a forklift and pinched the employee's arm against the metal bin. A preferable method would be to lower the sack so that the bottom is a few inches below the top of the bin and cut a slit horizontally around the bottom of the sack just above the top of the bin.

Discussion

We did not see airborne dust being generated as we watched employees emptying the Super Sacks or transferring glass beads into hoppers, bags, and boxes. This is not unexpected because the relatively large diameter glass beads (approximately 1 mm), once airborne, quickly settle. This was also confirmed by the very low concentrations of respirable and total dust found in the air samples (Tables 1 and 2) we collected. Overall, housekeeping appeared to be good throughout the facility.

Weissker required employees to wear respirators as protection from dust exposures. However, the results of PBZ air samples for respirable and total dust were below applicable OELs, suggesting that respiratory protection is not necessary. If Weissker continues to require employees to wear respirators the company must comply with all requirements in the OSHA respiratory protection standard, 29 CFR Part 1910.134. If employees are allowed to wear filtering-facepiece respirators on a voluntary basis, then the only requirement is providing them with a copy of Appendix D from the OSHA respiratory protection standard.

Due to concerns by the HHE requestors about arsenic and lead in the glass beads, we collected PBZ and surface and hand wipe samples for elements. We found very low levels of elements on the employees' hands and work surfaces. There are no standards for "acceptable" levels of workplace surface contamination with elements. However, surface contamination can provide information regarding the effectiveness of housekeeping practices

Discussion (continued)

(which was judged good during this evaluation) and the potential for dermal exposure or ingestion from contamination of workers' clothing or surfaces.

We measured no VOCs during the initial analysis of the glass bead bulk samples or during subsequent analysis of the silane coating on the Russian beads. Because the company ceased using the Chinese beads, no further analysis was done on potential emissions from the amine compound on those beads.

Conclusions

Weissker employees were not exposed to airborne concentrations of elements, respirable and total dust, silica, or formaldehyde above applicable OELs on the days of our evaluation. Tests of the glass bead coating on the Russian glass beads revealed no chemical hazards. Employees do not need respiratory protection when handling glass beads, but should use eye protection to prevent glass beads from getting in their eyes.

The fish-like odor and eye and upper respiratory tract irritation reported by some employees interviewed may have resulted from the amine-containing coating on Chinese glass beads previously purchased by Weissker.

Recommendations

Based on our findings, we recommend the actions listed below to create a more healthful workplace.

1. If employees are required to wear respirators, establish a respiratory protection program that meets the requirements of the OSHA respiratory protection standard 29 CFR Part 1910.134 (c). If employees wear respirators voluntarily, then they must be provided a copy of Appendix D of 29 CFR Part 1910.134. However, our air sampling results indicate that employees do not need to wear respirators.
2. Employees should wear safety glasses or goggles to prevent glass beads from getting in their eyes.
3. Instruct employees to wash their hands before eating, drinking, smoking, or touching their face.
4. Instruct employees to avoid placing their arms between a Super Sack container and the receiving bin when emptying

Recommendations (continued)

the Super Sacks. An option may be to lower the Super Sack container into the bin, and then make a horizontal cut around the bottom edge of the Super Sack above the metal bin.

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Respirable and Total Dust

Six full-shift PBZ air samples for respirable dust and four GA air samples for total dust were collected on tared 37-mm 5-µm pore size polyvinyl chloride filters at nominal flow rates of 1.7 Lpm (respirable dust) and 2.0 Lpm (total dust). The samples were analyzed per NIOSH Method 0600 for respirable dust and NIOSH Method 0500 for total dust. The respirable dust samples were also analyzed for silica by x-ray diffraction per NIOSH Method 7500 [NIOSH 2009].

Formaldehyde

Six PBZ and four GA full-shift samples for formaldehyde were collected using SKC UMEx 100 passive badges. The UMEx badge can detect formaldehyde in a range of 5 parts per billion to 5 ppm. The badges contain a tape impregnated with 2, 4-dinitrophenylhydrazine, which forms dinitrophenylhydrazine-hydrazone when exposed to formaldehyde [SKC 2007]. The samples were analyzed for formaldehyde by OSHA Method 1007 [OSHA 2009].

Elements

Fifteen full-shift air samples for elements were collected on 37-mm diameter cassettes containing 0.8-µm pore size mixed cellulose ester filters at a nominal flow rate of 2.0 Lpm. The samples were analyzed for elements using inductively coupled argon plasma-atomic emission spectroscopy per NIOSH Method 7303 with modifications [NIOSH 2009].

Wipe Samples

Fifteen wipe samples were collected to quantitatively assess the level of elements on employees' hands, and five were collected from workplace surfaces. For the hand wipe samples, we asked employees to wipe the palms and the backs of their hands with a moist towelette for 30 seconds both before and after their work shift. Flat surfaces (for example, tables) were sampled by placing a 10 centimeter x 10 centimeter template on the surface and wiping the area inside the template from top to bottom and then from left to right in an "S" pattern. The samples were digested and analyzed for elements per NIOSH Method 9102 with modifications [NIOSH 2009]. Sample results were reported by the laboratory as micrograms per wipe.

Statistical Methods

The minimum, maximum, and mean amount of arsenic, cadmium, chromium, copper, lead, manganese, and nickel detected on hand wipe samples collected before and after the employee's work shift was reported. When an element was not detectable on a wipe sample a value equal to the $LOD/\sqrt{2}$ was used to calculate the mean. For each element we compared the preshift and postshift amounts. We used a paired *t*-test for the analysis when the data appeared to be normally distributed and a paired sign test otherwise.

Bulk Samples

Three bulk samples of the glass beads were analyzed for VOCs by extraction with methanol and analysis by GC-MS. Another portion of each bulk was placed in a glass thermal desorption tube, secured at both ends with glass wool, and desorbed at 300°C for 10 minutes. The thermal unit was interfaced with a gas chromatograph with a mass selective detector. Particle sizing and characterization of four bulk samples of glass beads was performed using scanning electron microscopy. Six bulk samples of glass beads were digested and analyzed for elements per NIOSH Method 7303 [NIOSH 2009]. The silane coating on the Russian glass beads was analyzed by GC-MS to obtain a mass spectrum and determine its GC-MS retention time for comparison with sample analyses. Separate portions of glass beads were extracted with methanol and water and these solutions analyzed by GC-MS. Headspace analyses of the glass beads were performed using three-bed thermal desorption tubes. Samples were collected at ambient temperature above glass beads and above glass beads in water. The headspace samples were desorbed in an automatic thermal desorption system at 300°C for 10 minutes prior to analysis by GC-MS.

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Appendix B: Occupational Exposure Limits & Health Effects

In evaluating the hazards posed by workplace exposures, NIOSH investigators use both mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents as a guide for making recommendations. OELs have been developed by Federal agencies and safety and health organizations to prevent the occurrence of adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure to which most employees may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. However, not all employees will be protected from adverse health effects even if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the employee to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, which contributes to the individual's overall exposure.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL or ceiling values where health effects are caused by exposures over a short period. Unless otherwise noted, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that should not be exceeded at any time.

In the United States, OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits, while others are recommendations. The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits enforceable in workplaces covered under the Occupational Safety and Health Act. NIOSH RELs are recommendations based on a critical review of the scientific and technical information available on a given hazard and the adequacy of methods to identify and control the hazard. NIOSH RELs can be found in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2005]. NIOSH also recommends different types of risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects from these hazards. Other OELs that are commonly used and cited in the United States include the TLVs recommended by ACGIH, a professional organization, and the WEELs recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. They are not consensus standards. ACGIH TLVs are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2009]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2009].

Outside the United States, OELs have been established by various agencies and organizations and include both legal and recommended limits. Since 2006, the Berufsgenossenschaftliches Institut für Arbeitsschutz (German Institute for Occupational Safety and Health) has maintained a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States available at www.dguv.de/bgia/en/gestis/limit_values/index.jsp. The database contains international limits for over 1250 hazardous substances and is updated annually.

Employers should understand that not all hazardous chemicals have specific OSHA PELs, and for some agents the legally enforceable and recommended limits may not reflect current health-based information. However, an employer is still required by OSHA to protect its employees from hazards even in the absence of a specific OSHA PEL. OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. Thus, NIOSH investigators encourage employers to make use of other OELs when making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminate or minimize identified workplace hazards. This includes, in order of preference, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, or dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health that focuses resources on exposure controls by describing how a risk needs to be managed. Information on control banding is available at www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement the OELs, when available.

Elements

For this evaluation the elements of concern were elements that could be present in dust from the glass beads in the air and on surfaces. The air and bulk samples were analyzed for 31 elements: aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lanthanum, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, selenium, silver, strontium, tellurium, thallium, tin, titanium, vanadium, yttrium, zinc, and zirconium. Wipe samples were analyzed for the above elements with the exception of aluminum, antimony, calcium, lithium, magnesium, potassium, titanium, and zirconium.

Exposures to elements can manifest a variety of human health effects and are influenced by many factors including the dose and the route of exposure (e.g., manganese has a very low order of toxicity when ingested, but is much more toxic when inhaled as a fume). The toxicity of elements generally depends both on the chemical form of the element and the immune status, age, and lifestyle factors of the exposed worker. Exposures to low concentrations of elements over a long term may result in neurological, reproductive, teratogenic, cancer, and other health effects [LaDou 1990]. Several elements (arsenic, beryllium, cadmium, chromium, and nickel) are known to cause cancer. Attention to hygiene is important in reducing chronic health effects from workplace exposures.

Formaldehyde

Formaldehyde is a colorless gas with a strong odor. Exposure can occur through inhalation and skin absorption. Symptoms of exposure to low concentrations of formaldehyde may include irritation of the eyes, throat, and nose; headaches; nausea; nasal congestion; asthma; and skin rashes. NIOSH has identified formaldehyde as a suspected human carcinogen and recommends that exposures be reduced to the lowest feasible concentration [NIOSH1977]. NIOSH lists an REL for formaldehyde of 0.016 ppm for up to a 10-hour TWA exposure. The OSHA PEL is 0.75 ppm as an 8-hour TWA and 2 ppm as a STEL; formaldehyde is an OSHA-regulated carcinogen [29 CFR 1910.1048]. ACGIH has designated formaldehyde as a suspect human carcinogen and therefore recommends that worker exposure by all routes be carefully controlled to levels "as low as reasonably achievable" below the TLV. ACGIH has set a ceiling limit of 0.3 ppm for formaldehyde [ACGIH 2009]. This limit is intended to minimize eye and respiratory tract irritation. ACGIH also considers formaldehyde a sensitizer based on reports of allergic reactions.

Respirable and Total Dust

Respirable particulates are those that when inhaled can be deposited in the gas exchange region [ACGIH 2009]. Total dust, which includes respirable particulates, refers to particulates that may deposited anywhere in the respiratory tract. The OSHA 8-hour TWA PELs for respirable and total particulates (particulates not otherwise regulated) are 5 and 15 mg/m^3 respectively. ACGIH believes that all particles, even if they are biologically inert or insoluble, may have adverse health effects and therefore recommends that exposure to respirable particles not exceed 3 mg/m^3 and that exposures to inhalable particles not exceed 10 mg/m^3. These recommendations are for particles that do not have a specific TLV, are of low toxicity, and are referred to by ACGIH as particles (insoluble or poorly soluble) not otherwise specified [ACGIH 2009]. NIOSH does not have an OEL for particulates not otherwise specified/regulated.

Volatile Organic Compounds

VOCs are a large class of low molecular weight chemicals that are organic (i.e., containing carbon) and have a sufficiently high vapor pressure to allow some of the compounds to exist in the gaseous state at room temperature. The health effects associated with VOCs depend on the toxicity of the specific VOC, the level of exposure, and the duration of the exposure [EPA 2008]. Symptoms experienced from exposure to VOCs may include eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment [NIOSH 2005]. The most common route of exposure to VOCs is through inhalation, but some solvents may contribute to systemic health effects through skin absorption [Klaassen 2008; LaDou 1990]. The rate of systemic elimination of solvents depends on how volatile and lipophilic the chemicals are. Some subpopulations may be more susceptible to health effects from solvents based on age, sex, and genetics [Klaassen 2008]. VOCs are emitted in varying concentrations from numerous indoor sources including, but not limited to, carpeting, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, and combustion sources. Heating, burning, or chemical reactions may cause materials to emit VOCs. The most common work practice leading to solvent-related dermatitis is washing the hands with a solvent. Because solvents tend to combine with lipids, they can dry out the skin. NIOSH and ACGIH have recommended occupational exposure limits for many VOCs [NIOSH 2005; ACGIH 2009]. OSHA also has standards and/or PELs for many VOCs [29 CFR 1910.1000].

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Acknowledgments and Availability of Report

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found. HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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This report was prepared by Manuel Rodriguez and Carlos Aristeguieta of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies. Industrial hygiene field assistance was provided by SeungHee Jang. Statistical analysis was performed by Charles Mueller. Analytical support was provided by Bureau Veritas North America. Statistical support was provided by Charles Mueller. Health communication assistance was provided by Stefanie Evans. Editorial assistance was provided by Ellen Galloway. Desktop publishing was performed by Robin Smith.

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Below is a recommended citation for this report:
NIOSH [2009]. Health hazard evaluation report: evaluation of employees' chemical exposures while blending and repackaging glass beads for road markings, Palestine, TX. By Rodriguez M, Aristeguieta C. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA No. 2008-0017-3095.

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