UNITED STATES
DEPARTMENT OF TRANSPORTATION

2013 NESMEA Annual Meeting

"The Health Benefits of Glass Beads"

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Portsmouth, New Hampshire
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Outline

- The impact of heavy metals in glass beads used in pavement markings
- Safety benefits of wider edge lines
- Test method for quality of glass beads

Heavy Metals in Glass Beads

"Develop a science based understanding of the risk associated with the presence of heavy metals in glass bead products currently in commerce."

Screening Level Assessment of Arsenic and Lead Concentrations in Glass Beads Used in Pavement Markings (Draft Final Report)

The Evaluation Team

TEXAS A&M UNIVERSITY

Bryan Boulanger, CO-PI
Total, Extractable, & Bioaccessable Metals in Beads

Texas Transportation Institute

Paul Carlson, CO-PI
Retroreflectivity Measurements

EPA

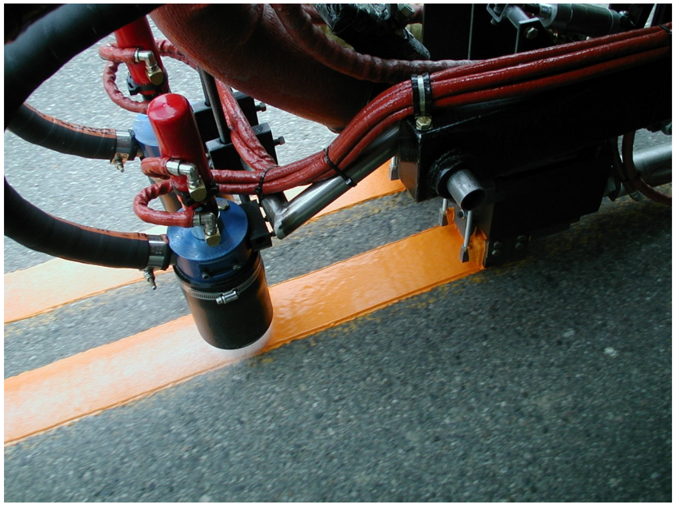
Thabet Tolaymat
Total & Extractable Metals in Beads

SAIC From Science to Solutions

Harry Fatkin
Conceptual Site Exposure Modeling

Purpose

Respond to public and industry concerns regarding potential hazards of heavy metals in glass beads used in pavement markings.

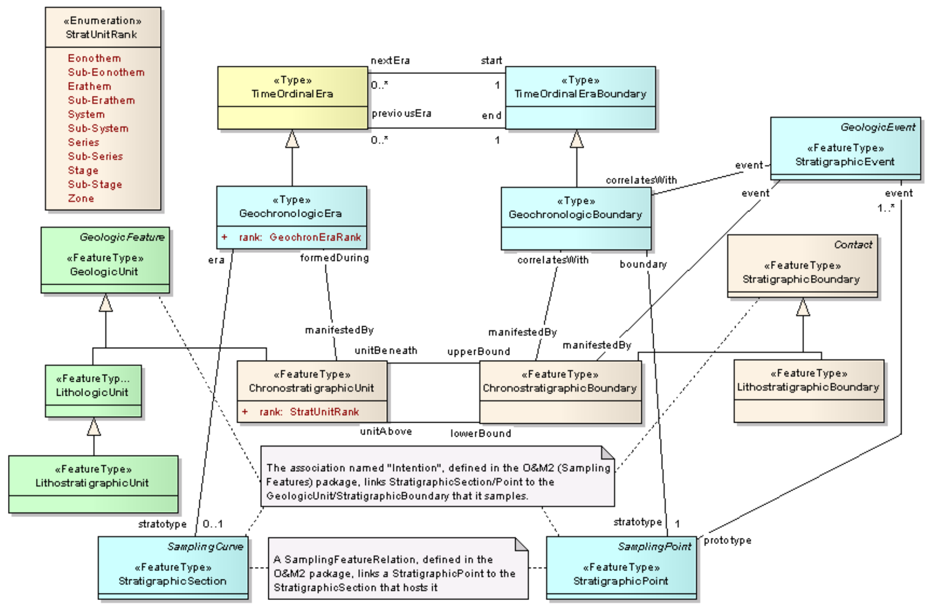


Purpose

Develop a full risk assessment posed by heavy metals in glass beads.

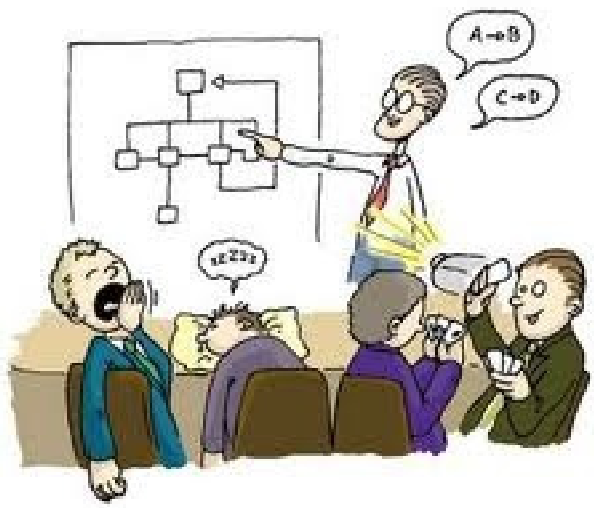
Purpose

Determine correlation between metal content in glass beads and potential environmental and human health risks.



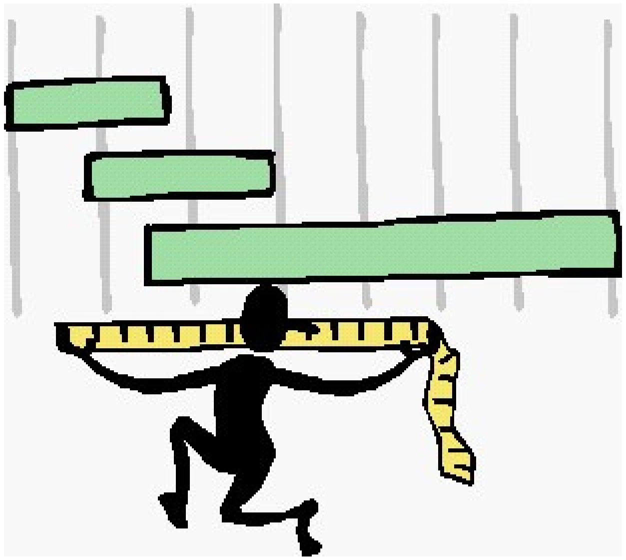
Purpose

Provide information to standardization bodies and industry regarding appropriate limits for heavy metals in glass beads.



Purpose

Provide guidance to industry and public agencies on methods to screen glass beads intended for use in pavement markings.



Purpose

Provide a framework for future studies.

Project Tasks

Phase 1

Task 1: Evaluation of total, extractable, and bioaccessable arsenic and lead content in glass bead samples provided by State DOTs

Task 2: Evaluate the relationship between total arsenic content in glass beads and the retroreflective performance of the beads

Task 3: Develop a conceptual site exposure model for occupational and residential exposures to arsenic and lead in glass beads

Task 1

Evaluation of As and Pb content in glass beads provided by State DOTs

	TEXAS A&M UNIVERSITY	EPA
# samples:	15	15
# replicates/sample:	3	2
Total Metals:	KOH Fusion Method Pacific Northwest National Laboratory	EPA Method 3052 HF Digestion
Extractable Metals:	EPA Method 3050B	EPA Method 3050B
Bioaccessable Metals:	Oral Bioavailability Method Kelley et al. (2002)	-
As and Pb analysis:	EPA Method 6020A ICP-MS	EPA Method 7010 GFAAS

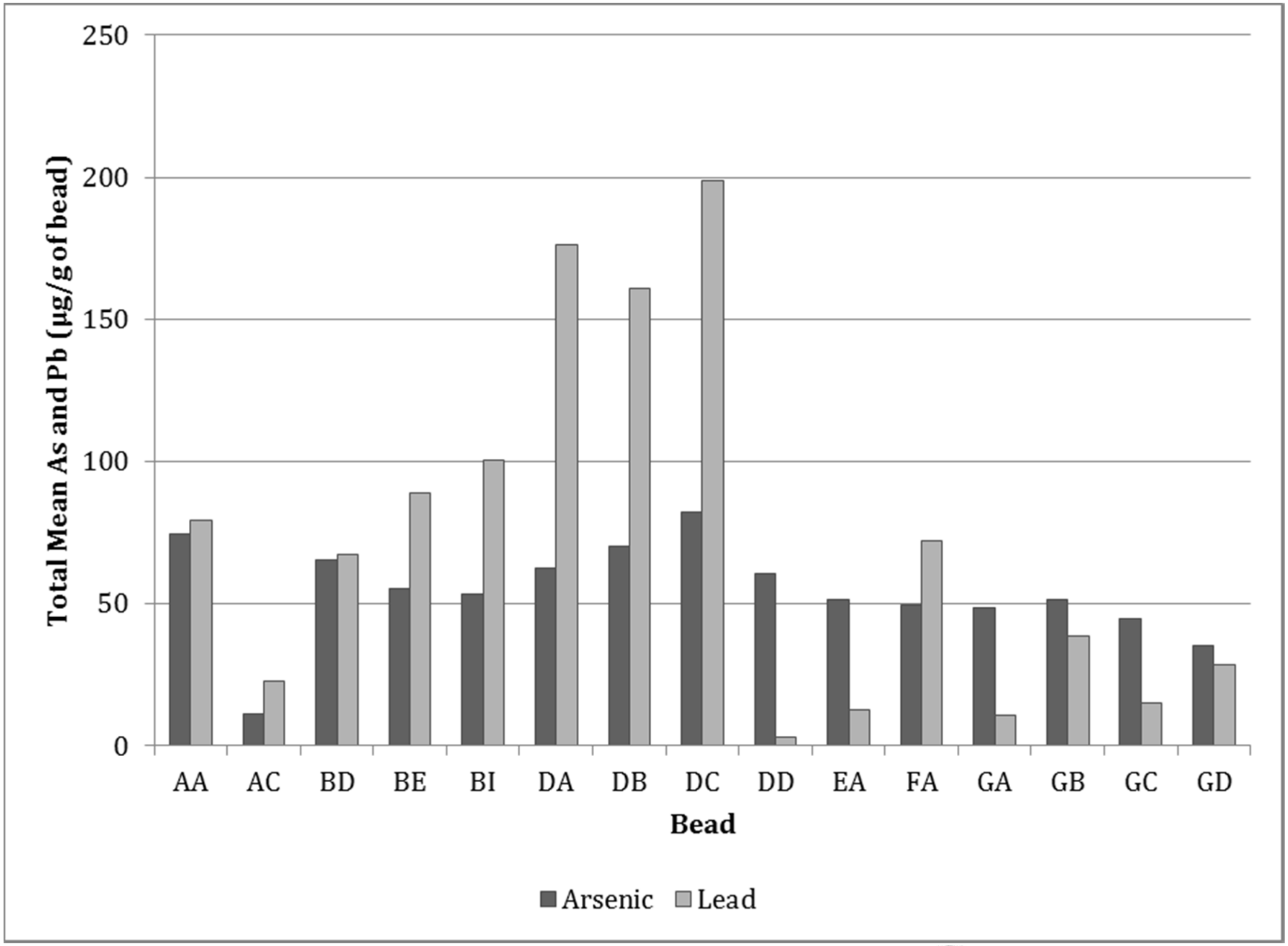
Task 1 - Results

As & Pd content (ppm) in glass beads provided by State DOT participants.

Bead	Total (ppm)		Extractable (ppm)		Bioaccessible (ppm)	
	arsenic	lead	arsenic	lead	arsenic	lead
AA	75 ± 27	79 ± 50	BDL	0.38 ± 0.1	BDL	BQL
AC	11 ± 8	22 ± 19	BDL	0.74 ± 0.5	BDL	3.6 ± 5.4
BD	65 ± 36	67 ± 58	BDL	0.21 ± 0.1	BDL	BQL
BE	55 ± 24	89 ± 62	BDL	0.70 ± 0.3	BDL	BQL
BI	53 ± 25	100 ± 71	BDL	3.29 ± 1.0	BDL	1.7 ± 2.4
DA	62 ± 31	176 ± 154	BDL	$0.25 \pm 2 \times 10^{-3}$	BDL	BQL
DB	70 ± 40	161 ± 186	BDL	BDL	BDL	BDL
DC	82 ± 65	199 ± 246	BDL	BQL	BDL	BQL
DD	61 ± 27	3 ± 7	BDL	BDL	BDL	BDL
EA	51 ± 30	13 ± 13	BDL	BDL	BDL	BDL
FH	50 ± 20	72 ± 36	BDL	0.31 ± 0.1	BDL	0.19±0.01
GA	49 ± 34	10 ± 9	BDL	BDL	BDL	BDL
GB	52 ± 22	38 ± 33	BDL	BDL	BDL	BDL
GC	45 ± 15	15 ± 6	BDL	BDL	BDL	BDL
GD	35 ± 37	28 ± 26	BDL	BDL	BDL	BDL

BQL - Below Quantification Limits (<0.1 µg/g for arsenic and lead)
BDL - Below Detection Limits (<0.07 µg/g for arsenic, <0.004 µg/g for lead)

Task 1 - Results



Task 1 - Results

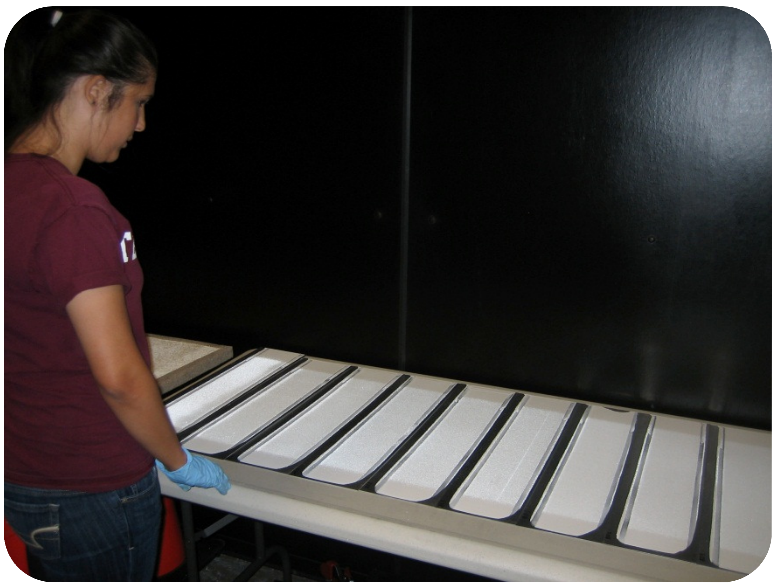
Intra-method comparison for total As & Pb in the 15 glass bead samples.

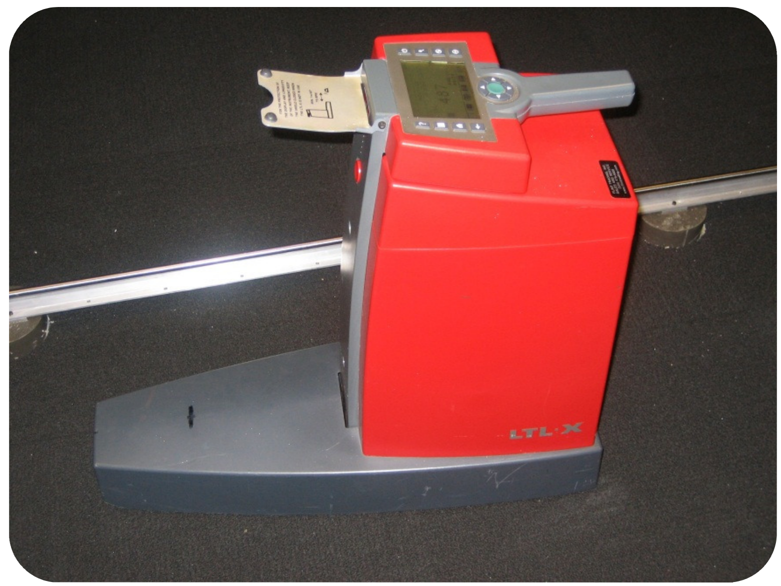
Method	Agency	Arsenic		Lead	
		# of samples with measurable arsenic	mean content when present (ppm)	# of samples with measurable arsenic	mean content when present (ppm)
Portable XRF	FL DOT	2 of 15	8.5	3 of 15	15
Benchtop XRF	FHWA	6 of 15	1.0	10 of 15	15
EPA Method 3052	EPA	15 of 15	1.3	15 of 15	8.2
KOH Fusion	TAMU	15 of 15	51	15 of 15	68

Results from KOH Fusion were used as providing most conservative estimate

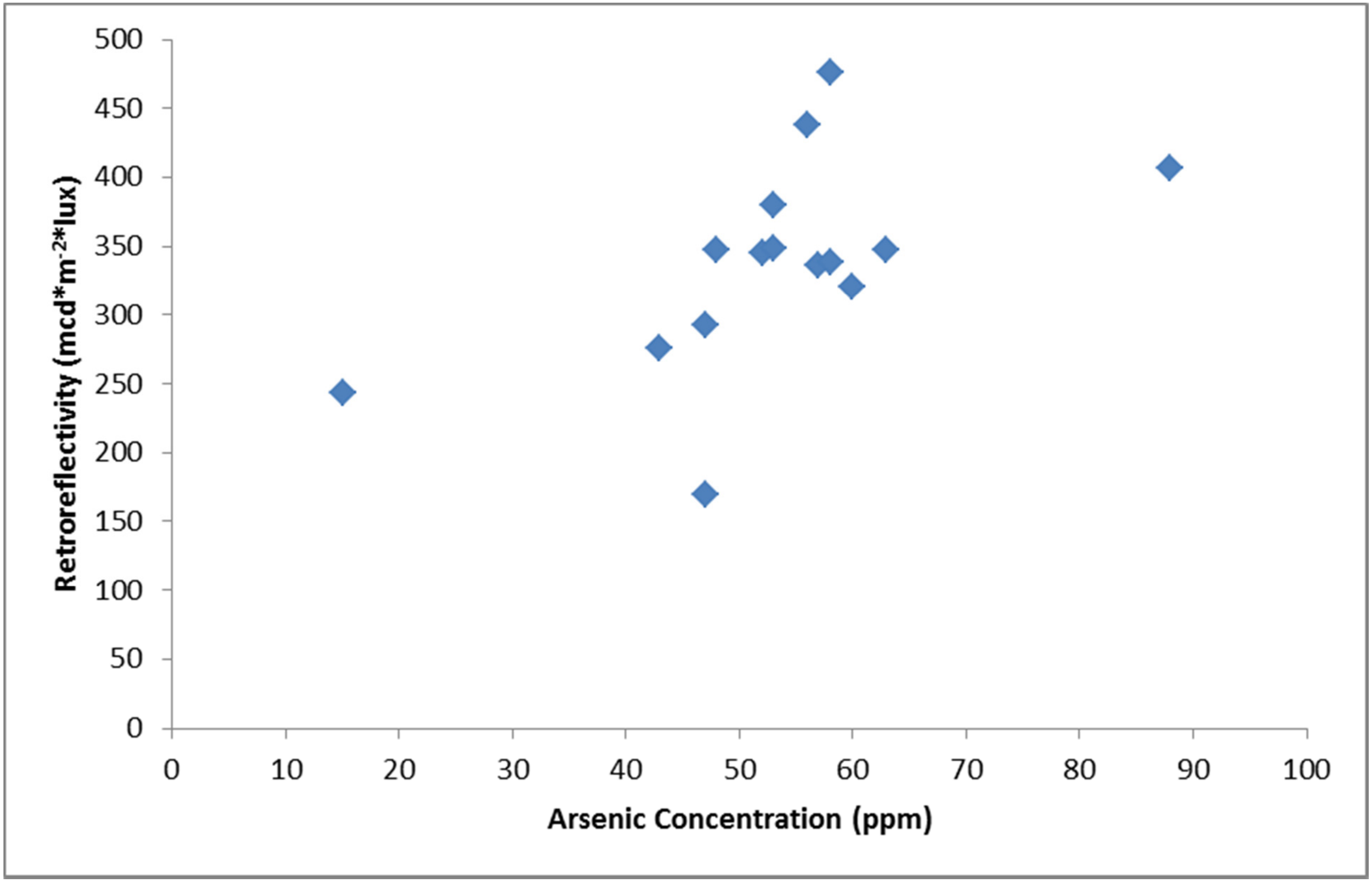
Task 2

Evaluate relationship between total As content and retroreflectivity





Task 2 – Results

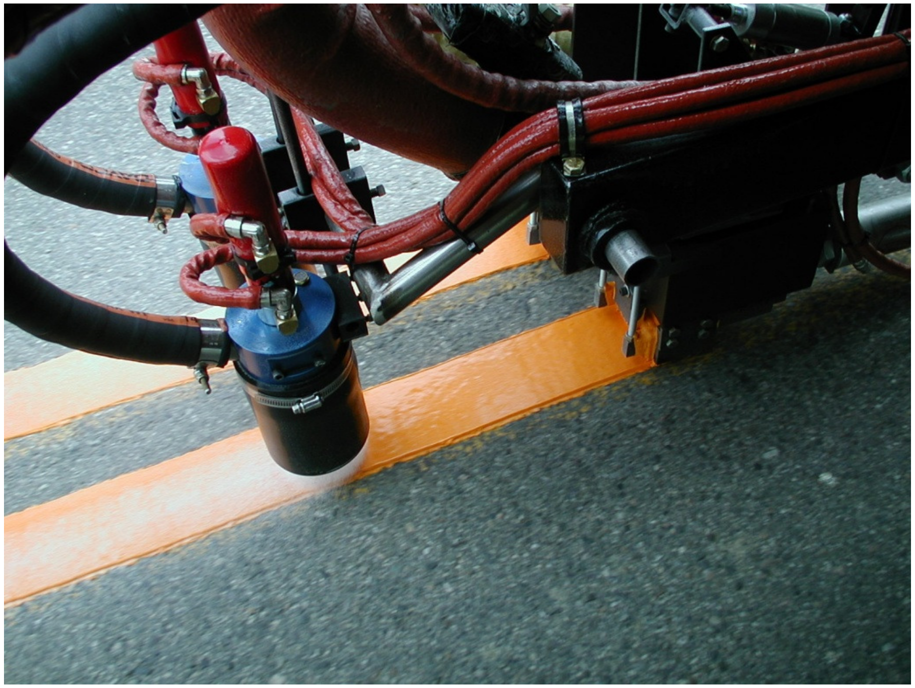


Task 3

Develop conceptual site exposure model (CSEM) for occupational and residential exposures to As and Pb in glass beads

Considering exposures occurring during:

- Manufacturing
- Transportation
- Storage/Transfer
- Application
- Wear/Abrasion
- Removal/Disposal



Task 3

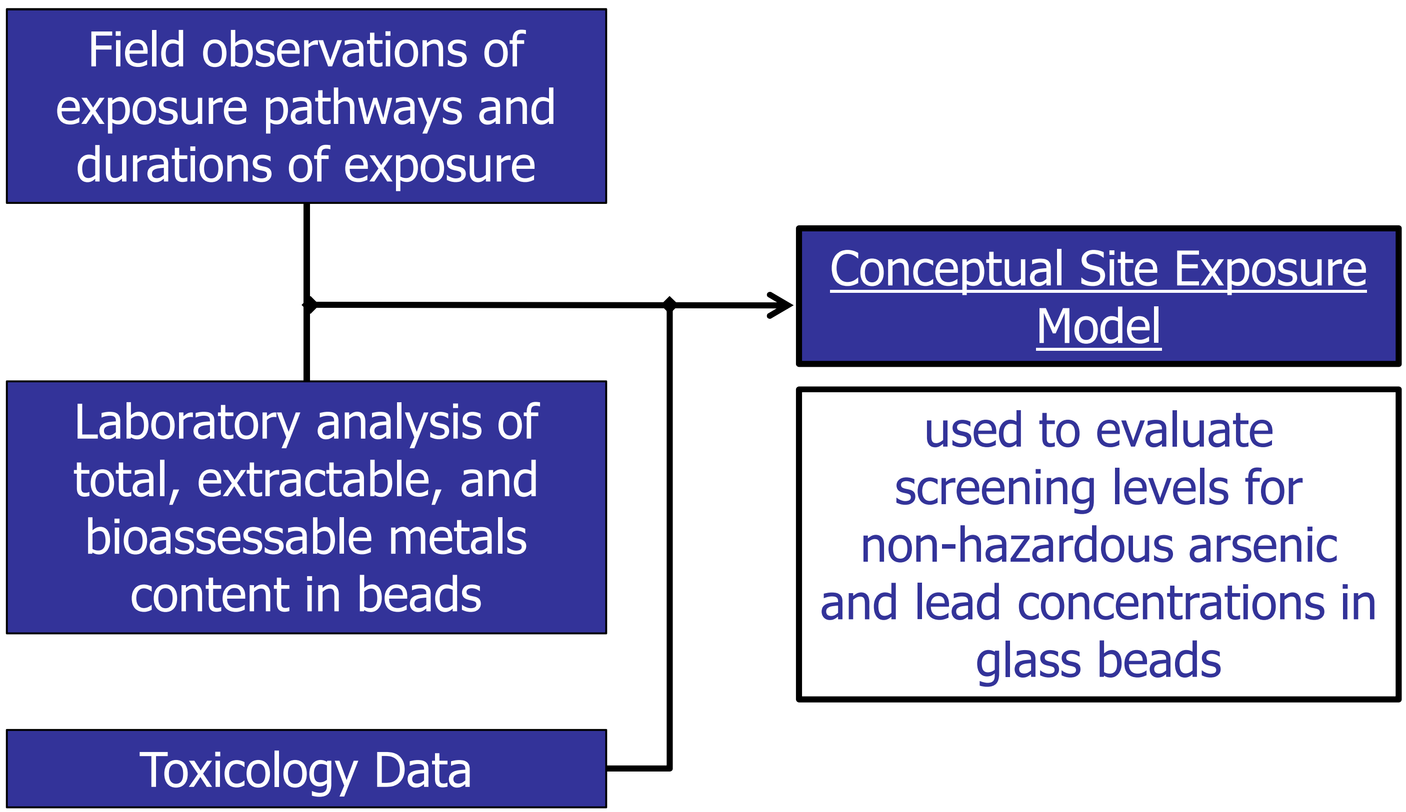
Develop conceptual site exposure model (CSEM) for occupational and residential exposures to As and Pb in glass beads

for both occupational & residential exposure scenarios including:

- direct contact with beads
- indirect contact with bead contaminated soil, contaminated groundwater, and airborne particulates

Task 3

Develop conceptual site exposure model (CSEM) for occupational and residential exposures to As and Pb in glass beads



Task 3 – Results

Based upon the completed exposure assessment, the proposed risk assessment model focused on three specific exposure scenarios, including:

- **Scenario 1 – Worker**: roadway marking crew employee exposed through incidental ingestion, dermal contact, and inhalation of fugitive dust emissions.
- **Scenario 2 – Adult Resident**: resident living in close proximity to an active bead storage yard or on top of a former storage yard exposed through ingestion of contaminated drinking water, incidental ingestion, dermal contact, and inhalation of fugitive dust emissions.
- **Scenario 3 – Child Resident**: resident living in close proximity to an active bead storage yard or on top of a former storage yard exposed through ingestion of contaminated drinking water, incidental ingestion, dermal contact, and inhalation of fugitive dust emissions.

Project Tasks

Phase 2

Task 4: Analyze glass bead content of soils

Task 5: Develop model-derived human health screening levels for arsenic and lead in glass beads

Task 4

CSEM model development indicated the concentration of beads in soil at a storage facility would be an important parameter in developing human health screening levels.

- 5 Samples taken from a bead storage and transfer facility at a commercial pavement marking company
- Facility in use for >20 years
- Respirable fraction is that portion of soil <10µm in size

Task 4 - Results

Sample ID	Weight % of glass beads in soil	Arsenic (ppm)	Lead (ppm)	Arsenic in respirable fraction (ppm)
Sample 1	24.5%	2.9 ± --†	120 ± 160	BDL
Sample 2	19.8%	BDL	40 ± 19	BDL
Sample 3	48.0%	7.6 ± 0.5	35 ± 2.1	BDL
Sample 4	41.2%	BDL	14 ± 11	BDL
Sample 5	78.3%	BDL	12 ± 5.1	BDL
Control	0%	BDL	24 ± 12	BDL
SRM	--	BDL	22 ± 4.6	BDL

† Only one reportable data point out of three replicates
BDL Below Detection Limit (< 2.8 µg/g for As , <0.44 µg/g for Pb)

Task 5

Develop conservative screening levels for protection of human health risk from glass bead exposure.

- Exposure pathways for the three exposure scenarios were identified during field investigations of bead work flow.
- Exposure pathways included within the model were:
  - incidental ingestion of beads,
  - incidental inhalation of beads, and
  - ingestion of bead contaminated groundwater.
- The potential for leaching of arsenic to groundwater was evaluated using laboratory generated characterization data.
- Lead and arsenic toxicity data used in the risk evaluation are from the Risk Assessment Information System (RAIS) maintained by the Oak Ridge National Laboratory.

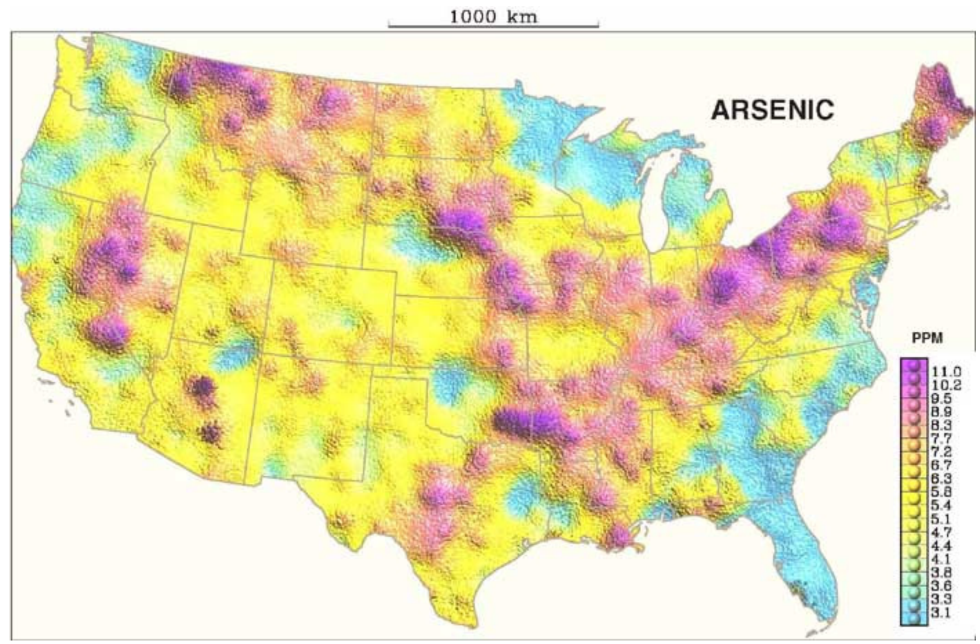
Task 5 – Results

Derived screening levels for protection of human health.

	Screening Level (ppm)	
	Arsenic	Lead
Adult Resident Scenario		
Carcinogenic	620	-
Non-cancer	12,000	**580**
Child Resident Scenario		
Carcinogenic	**220**	-
Non-cancer	1,700	1050
Worker Scenario		
Carcinogenic	1,000	-
Non-cancer	17,000	**580**

Words of Caution

- Workers should wear gloves and respirators.
- Reduce bead spillage during transfer operations.
- Reduce bead loss during short line applications.
- Use vacuum recovery systems during pavement marking removal.



- Other components in pavement markings (and pavements) may be of greater concern to human health.

Wider Edge Lines

"What are the safety effects of wider edge lines on rural, two-lane highways?"

Accident Analysis and Prevention 48 (2012) 317-325

Wider Edge Lines

- The safety effect of wider edge lines was examined by analyzing crash frequency data for road segments with and without wider edge lines.
- The data from three states, Kansas, Michigan, and Illinois, were analyzed.
- Because of different nature of data from each state, a different statistical analysis approach was employed for each state:
  - an empirical Bayes, before-after analysis of Kansas data,
  - an interrupted time series analysis of Michigan data, and
  - a cross sectional analysis of Illinois data.

Wider Edge Lines - Results

Crash Type	Percent Crash Reduction			
	KS	MI (Analysis 1)	MI (Analysis 2)	IL
Total	**17.5**	**27.4**	**19.4**	**30.1**
Fatal Injury	**36.5**	15.4	16.1	**37.7**
PDO	**12.3**	**30.5**	**19.6**	**23.9**
Day	**28.6**	**20.3**	12.0	**29.1**
Night	3.7	**30.7**	**18.8**	**29.9**
Daytime Fatal Injury	**41.5**	8.2	23.0	**36.0**
Nighttime Fatal Injury	12.7	22.6	-5.8	**34.2**
Wet	**22.9**	**67.2**	**62.6**	**34.7**
Wet Night	24.3	**76.9**	**79.2**	35.7
Single Vehicle	**27.0**	**30.0**	**18.7**	**37.0**
Single Vehicle Wet		**73.8**	**65.9**	**32.8**
Single Vehicle Night	**18.4**	**29.4**	**18.0**	**29.5**
Single Vehicle Fatal Injury	**36.8**	10.0	-1.9	**42.2**
Single Vehicle Night Fatal Injury	18.7	9.7		**36.3**
Older Driver				**24.1**
Fixed Object	**19.0**			**29.5**

Quality of Glass Beads

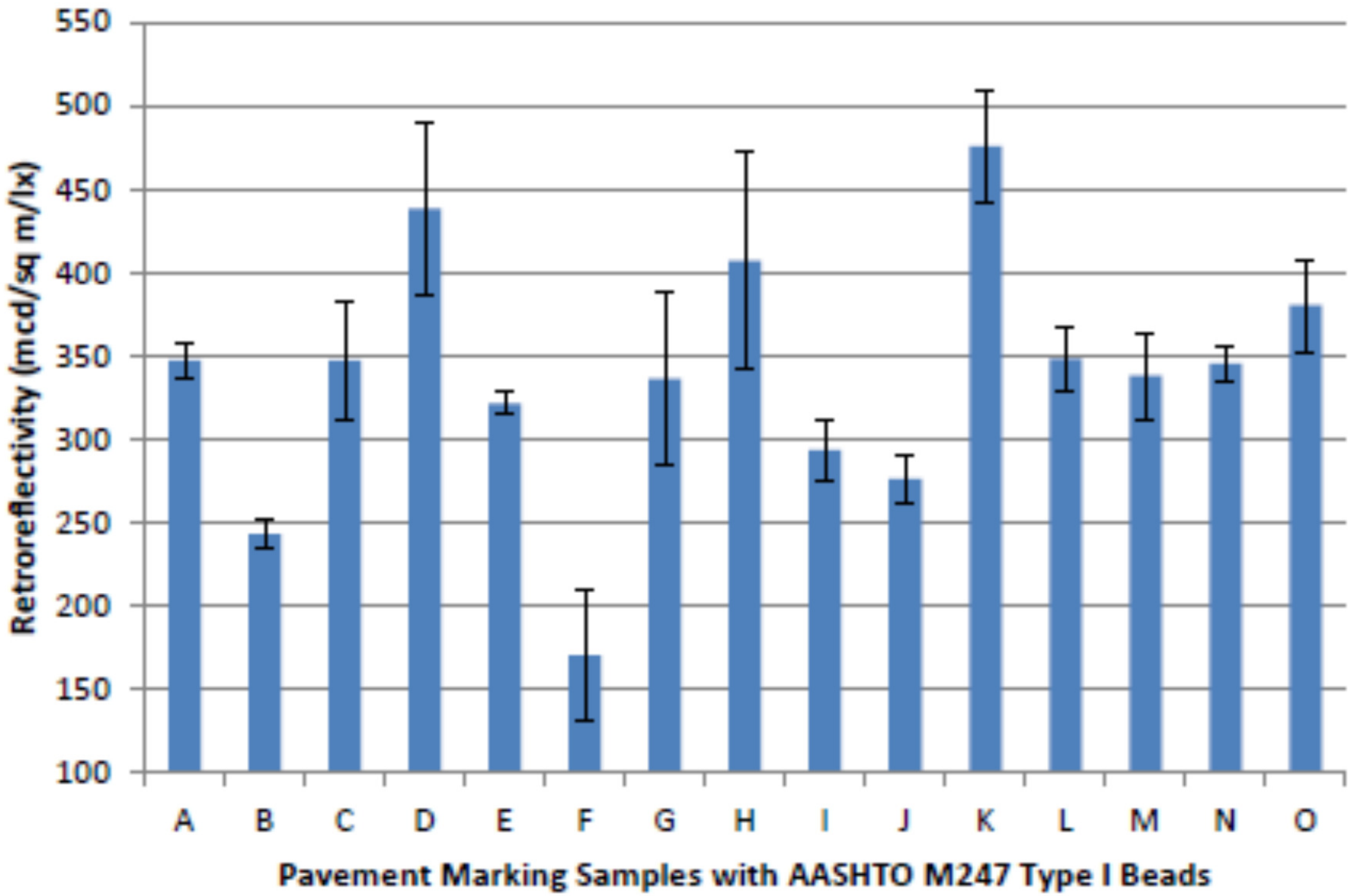
"Develop a recommended laboratory test to predict the initial retroreflectivity of pavement markings in the field based on the quality of the glass beads"

NCHRP Report 743: Predicting the Initial Retroreflectivity of Pavement Markings from Glass Bead Quality (2013)

Quality of Glass Beads

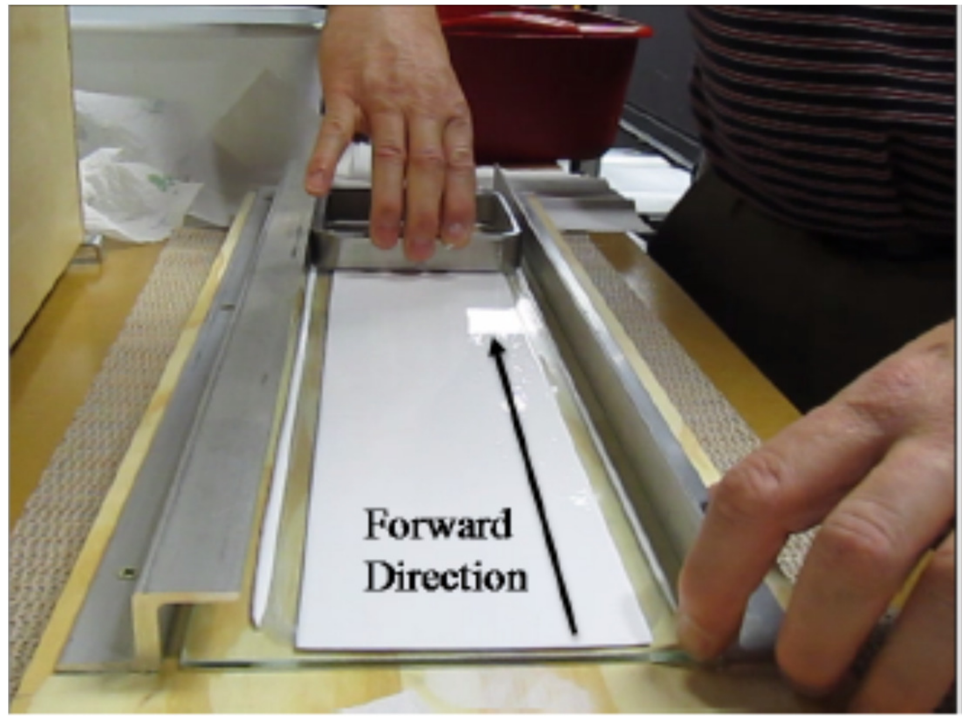
- 15 samples of Type I AASHTO M247 glass beads were used to make three drawdowns each of pavement marking samples using waterborne paint at 15 mils.
- Retroreflectivity of the samples were measured 5 times in each direction. An overall average and standard deviation were calculated for each sample of glass beads.
- Two of the 15 samples did not provide retroreflectivity values of 250 $mcd/m^2/lux$, or greater.

Quality of Glass Beads



Quality of Glass Beads – Results

- Developed a drawdown test method, which was proven to be repeatable and reproducible based on an interlaboratory study of 5 labs.
- Developed and validated a statistically significant relationship between laboratory and field retroreflectivity.



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