Particle Collection Efficiency Difference of a HI-Vol Particulate Collection System and a R&P 1400AB TEOM Particulate Collection System

Red Dog Mine Site **March 2006**

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Background

Teck Cominco Alaska, Incorporated (TCAK) operates the Red Dog Mine, which is located approximately 90 miles northeast of Kotzebue, Alaska and 47 miles inland of the Chukchi Sea.

From January 1992 to August 1994 TCAK monitored Total Suspended Particulates and airborne lead using Wedding HI-Vol particulate samplers configured for Total Suspended Particulate (TSP) sample collection. During the monitoring period, the frequency of collection of a 24-hour sample ranged from daily to a 1 in 6 schedule.

Currently TCAK monitors Total Suspended Particulates, airborne lead, and airborne zinc using Rupprecht & Patashnick 1400 AB TEOM ambient particulate monitors (TEOM) equipped with TSP Inlets and Automatic Cartridge Collection Units (ACCU). The units measure TSP concentration every two seconds and record the hourly average TSP concentration. The ACCU collects a sample for airborne zinc and lead on a preset schedule, the collection schedule range from a 1 in 2 schedule to a 1 in 6 schedule. All monitoring is done within the ambient air boundary and is conducted to provide operation understanding and increased control of dust generation.

The purpose of this project is to develop a relationship between the TEOM and HI-Vol systems. The systems ability to measure TSP, lead and zinc will be compared. The relationship will be incorporated into the historic fugitive emission model for the Red Dog Mine that is currently under development.

Project Summary

The monitoring program consisted of the comparison of two monitoring systems. The monitoring systems collected TSP on a 1 in 2 day schedule. Following collection the filters were analyzed for TSP, lead, and zinc.

The HI-Vol particulate monitoring station utilized a total suspended particulates sample inlet. Ambient air was drawn into a covered housing and through a 8 ½ by 11 inch quartz fiber filter by a high-flow-rate blower at 1.1 to 1.7 m^3/min allowing TSP in sizes up to 25 to 50 μm to collect on the filter surface. This system was capable of collecting TSP samples for 24 hours. The total volume of air sampled will be measured and corrected to standard conditions. The particulate matter was analyzed for TSP, lead and zinc.

The TEOM particulate monitor station utilized a total suspended particulates sample inlet. Ambient air drawn into the inlet by a low flow vacuum pump at 16.67 l/min allows TSP in sizes up to 50 μm to be collected. The inlet flow was split into two separate flows. The main flow at 3.0 l/min was continuously monitored for TSP concentration by passing the flow through a filter attached to a microbalance. The bypass flow, at 13.67 l/min, was directed through the ACCU filter unit programmed to collect a 24 hour TSP sample on a 1 in 2 day schedule. The TSP concentration was measured every 2 seconds and the hourly average TSP concentration was recorded. The hourly average TSP results are used to

calculate the 24 hour midnight to midnight TSP concentration. The ACCU filter particulate matter was analyzed for zinc and lead.

Cooper Environmental Services (CES), acting as a subcontractor for TCAK, performed the XRF analysis of the filters. The XRF analyses follow technical and regulatory criteria as established in the CES XRF-PM standard operating procedure (SOP). This SOP, which was designed in accordance with *EPA QA/G-6 Guidance for the Preparation of Standard Operating Procedures for Quality Related Documents*, is a modified version of the standard method *IO-3.3 Determination of Metals in Ambient Particulate Matter Using X-Ray Fluorescence.* The standard method has been modified to allow for use of CES's Spectrace QuanX analyzer.

Monitor Locations

The program was located within the ambient air boundary of the Red Dog mine site. The sampler inlets were located on the southeast corner of the roof of the main building of the Personnel Accommodation Complex (PAC), in the same location as the PAC 1, PAC 2, and PAC 3 sample sites of the 1992 to 1994 monitoring program. Figure 1 is a detail of the sample site location with the major particulate sources identified. Pictures taken from the site in the four cardinal directions can be found in Figures 2 to 5. Potential particulate source measured by the monitors are the Gyratory and Jaw Crushers, visible in Figure 6.

Figure 1: Sample Site Location and Surrounding Particulate Sources

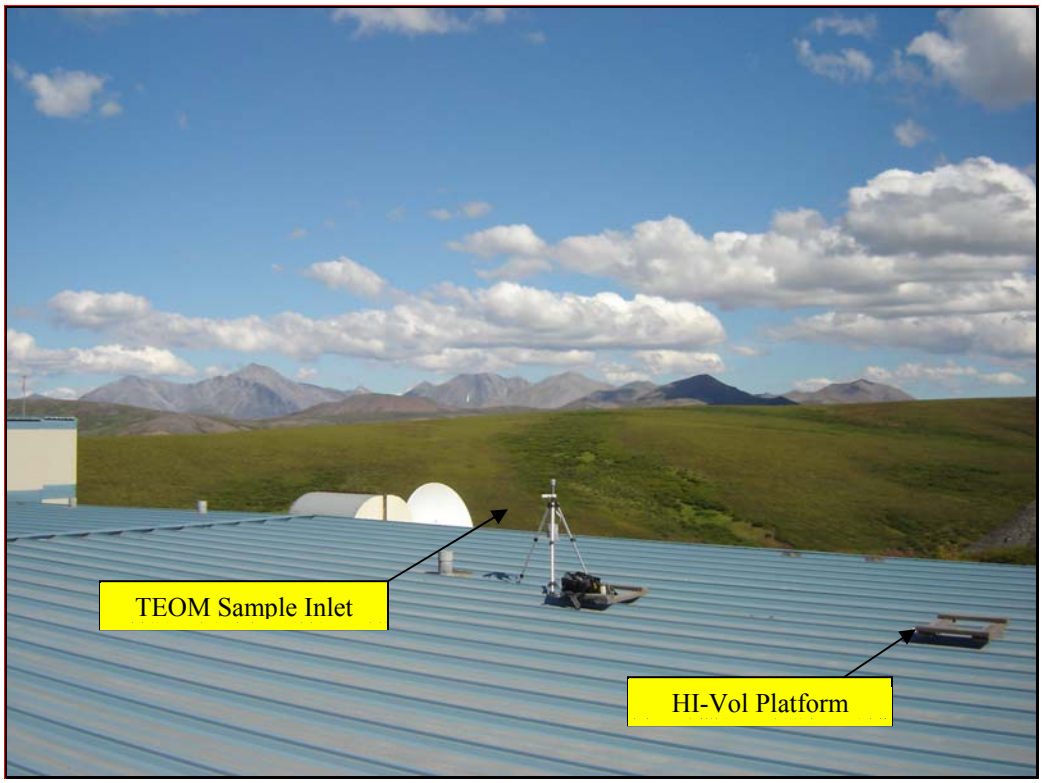

Figure 2: View Facing North

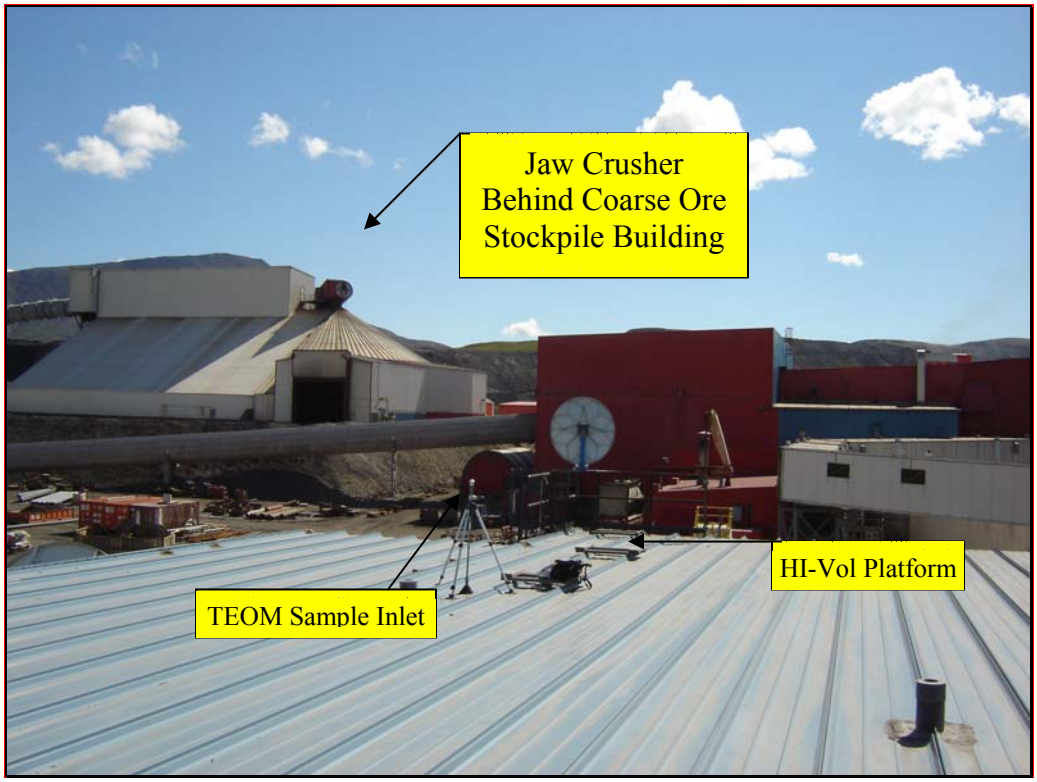

Figure 3: View Facing East

Figure 4: View Facing South

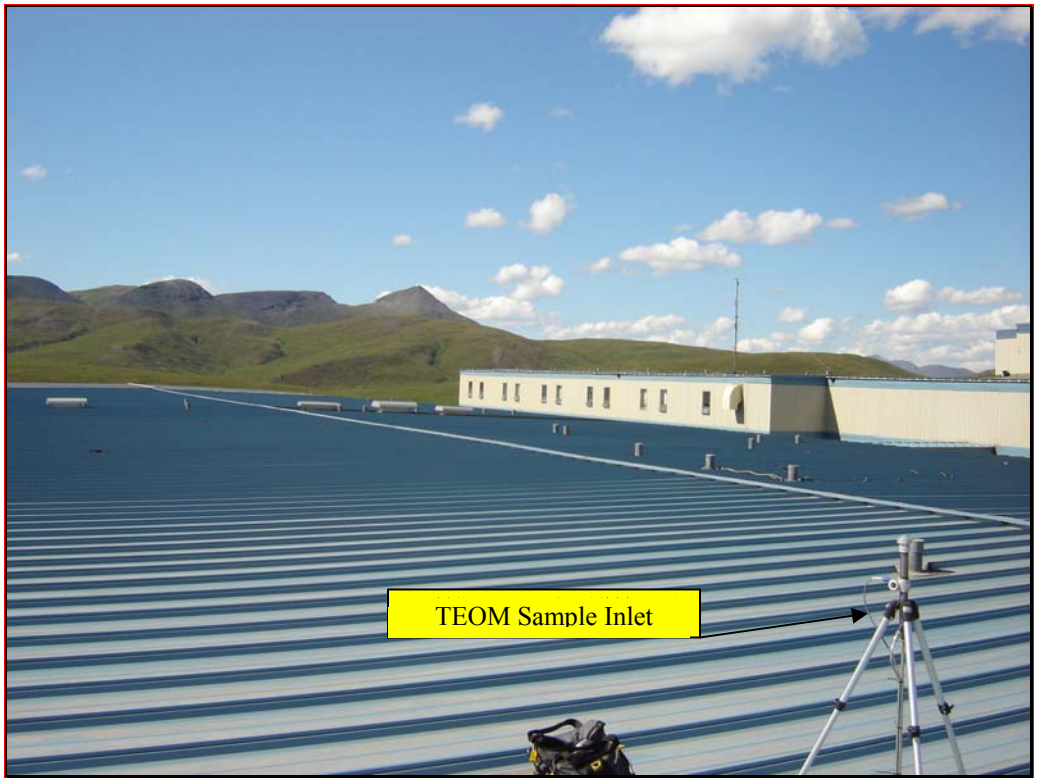

Figure 5: View Facing South

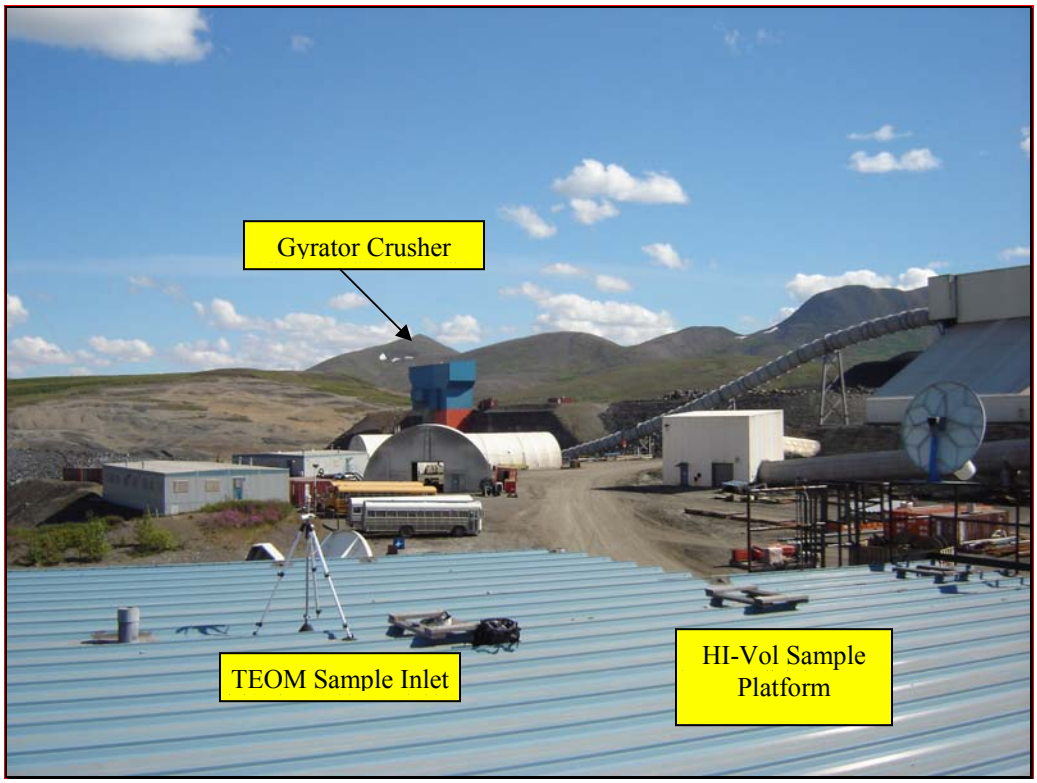

Figure 6: View Facing East Northeast

Equipment Description

The study was designed to compare the TSP, lead, and Zinc collection efficiency of a Wedding Hi-Vol sampler and a R&P 1400AB sampler. The TSP, lead and zinc results of the two instruments were used to develop a comparison factor. The comparison factor will be used to compare past Wedding HI-Vol monitoring programs to the current R&P 1400AB monitoring program. The co-located samples were collected on a 1 in 2 day schedule. The scheduled run days were a modification of the EPA 1 in 6 day schedule with every third sample falling on a 1 in 6 day sample day.

Wedding Hi Vol

This equipment consists of a blower motor, critical orifice, and support screen on which a glass fiber filter is placed. The equipment was housed in an aluminum shelter equipped with a hinged roof. Control of the sampler was via relays activated by a Campbell Scientific CR10 data logger. The data logger was equipped with a pressure transducer, which will record the actual flow at 2-second intervals. Additionally, a thermister located in a radiation shield was used to continually measure the ambient air temperature.

The Wedding HI-Vol monitoring system consists of the following components.

Item	Manufacturer	Model Name
TSP Sampler	Wedding & Associates, Inc.	Critical Flow High Volume Sampler
Data Logger	Campbell Scientific	CR10
Pressure Transducer	Omega	N/A
Thermometer	Campbell Scientific	107
Filter Unit	Whatman	QM-A Quartz

R&P 1400AB TEOM Monitor

The equipment consists of a TEOM Sensor unit, TEOM Control unit, TSP sample inlet, flow splitter, ACCU unit, and vacuum pump. The sensor and control units were housed in a room inside the PAC. The sample inlet and flow splitter were located above the roof and are connected to the sensor unit by stainless steel tubes. The sample inlet was at the same height above the roof line as the HI-Vol critical orifice.

The R&P TEOM monitoring system consists of the following components.

Item	Manufacturer
1400AB Sensor Unit	Rupprecht & Patashnick Co
1400AB Control Unit	Rupprecht & Patashnick Co
TSP Inlet	Rupprecht & Patashnick Co
Flow Splitter	Rupprecht & Patashnick Co
Automatic Cartridge Collection Unit	Rupprecht & Patashnick Co

The system uses two types of filters. The TSP is determined using a TX40 filter mounted on an oscillating microbalance. The metal sample is collected on a Whatman PP Ring Supported 2µm PTFE 46.2mm filter.

Rationale for Design

The equipment was selected based on the request by ADEC to develop a relationship between the currently operated system and the system in operation in 1992 to 1994. The operating systems are located within the Red Dog Mine Ambient Air boundary and are not used for determination of compliance with National Ambient Air Quality Standards (NAAQS).

Scheduled Measurement Activities

Measurement activities begun on August 8, 2005 and ended on October 21, 2005. The project scheduled run days can be found in figure below.

August 2005						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

September 2005						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

October 2005						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Sample Run Date

Figure 7: 1 in 2 Day Sample Schedule

Results

The 24-hour average Total Suspended Solids (TSP), lead and zinc results for all of the sample runs is presented the table below.

	Wedding HI-Vol			R&P TEOM		
Sample Date	TSP ug/m^3	Lead ug/m^3	Zinc ug/m^3	TSP ug/m^3	Lead ug/m^3	Zinc ug/m^3
8/8/2005	26	0.79	2.31	17	0.34	0.99
8/10/2005	68	0.94	4.07	40	0.41	1.30
8/12/2005	29	1.43	4.26	20	0.67	1.66
8/14/2005	42	0.34	1.29	37	0.13	0.35
8/16/2005	46	0.35	1.24	22	0.05	0.10
8/18/2005	94	1.32	3.84	50	0.23	0.61
8/20/2005	23	0.38	1.69	15	0.16	0.48
8/22/2005	22	0.43	2.07	12	0.18	0.63
8/24/2005	3	0.00	0.48	3	0.01	0.03
8/26/2005	19	0.30	1.53	11	0.15	0.41
8/28/2005	14	0.34	1.16	7	0.12	0.30
8/30/2005	9	0.09	0.81	6	0.05	0.17
9/1/2005	63	1.39	4.41	32	0.60	1.61
9/3/2005	8	0.10	0.72	6	0.03	0.07
9/5/2005	88	1.05	2.28	36	0.21	0.44
9/7&9/2005*	78	1.05	2.56	47	0.19	0.51
9/11/2005	287	0.69	2.47	10	0.19	0.56
9/13/2005	13	0.21	1.07	7	0.05	0.15
9/15/2005	11	0.13	0.84	5	0.04	0.15
9/17/2005	18	0.21	0.90	9	0.05	0.14
9/19/2005	10	0.09	0.78	6	0.03	0.08
9/21/2005	35	0.31	3.95	5	0.05	0.19
9/23/2005	25	0.49	1.83	17	0.26	0.74
9/25/2005	14	0.15	0.84	7	0.05	0.17
9/27/2005	26	0.19	0.97	6	0.05	0.18
9/29/2005	602	6.51	8.74	412	1.97	2.05
10/1/2005	1038	10.36	15.94	421	0.39	0.77
10/3/2005	120	1.61	4.46	58	0.51	1.82
10/5/2005	158	1.68	3.07	68	2.72	3.10
10/7/2005	319	5.35	10.24	151	0.68	1.40
10/9/2005	308	3.60	5.58	160	0.93	1.30
10/11/2005	745	10.17	18.18	338	1.41	2.02
10/13/2005	40	1.15	1.58	32	0.44	0.92
10/15/2005	29	0.29	1.36	11	0.21	0.58
10/17/2005	49	0.40	1.07	23	0.15	0.25
10/19/2005	17	0.31	1.30	16	0.19	0.50
10/21/2005	30	0.26	1.28	36	0.17	0.46

*Hi-Vol Filter was double exposed. The results from two filters used for the TEOM results.

After reviewing the data several data points were removed from the analysis as obvious outliers. The outliers were most likely the result of sample contamination during the multiple sample handling steps required for the TSP and metals analysis.
Below is a table summarizing the data used in the comparison analysis, an * indicates that the data point was used in the analysis.

Sample Date	**TSP**	TSP<100	Lead	**Zinc**
8/8/2005	*	*	*	*
8/10/2005	*	*	*	
8/12/2005	*	*		
8/14/2005	*		*	*
8/16/2005	*	*		
8/18/2005	*	*		
8/20/2005	*	*	*	*
8/22/2005	*	*	*	
8/24/2005	*	*	*	*
8/26/2005	*	*	*	*
8/28/2005	*	*	*	*
8/30/2005	*	*	*	*
9/1/2005	*	*	*	
9/3/2005	*	*	*	*
9/5/2005	*			
9/7&9/2005	*	*		
9/11/2005				
9/13/2005	*	*	*	*
9/15/2005	*	*	*	*
9/17/2005	*	*	*	*
9/19/2005	*	*	*	*
9/21/2005	*			
9/23/2005	*	*	*	*
9/25/2005	*	*	*	*
9/27/2005	*		*	*
9/29/2005				
10/1/2005	*			
10/3/2005	*			
10/5/2005	*			
10/7/2005	*			
10/9/2005	*			
10/11/2005	*			
10/13/2005	*		*	
10/15/2005	*		*	*
10/17/2005	*	*	*	*
10/19/2005	*		*	*
10/21/2005	*		*	*

Total Suspended Solids Comparison

Using all data points collected, a liner comparison of the Hi-Vol TSP concentration to the TEOM TSP concentration results in a particle collection difference of 46% with a correlation coefficient of 0.91 (Figure 8).

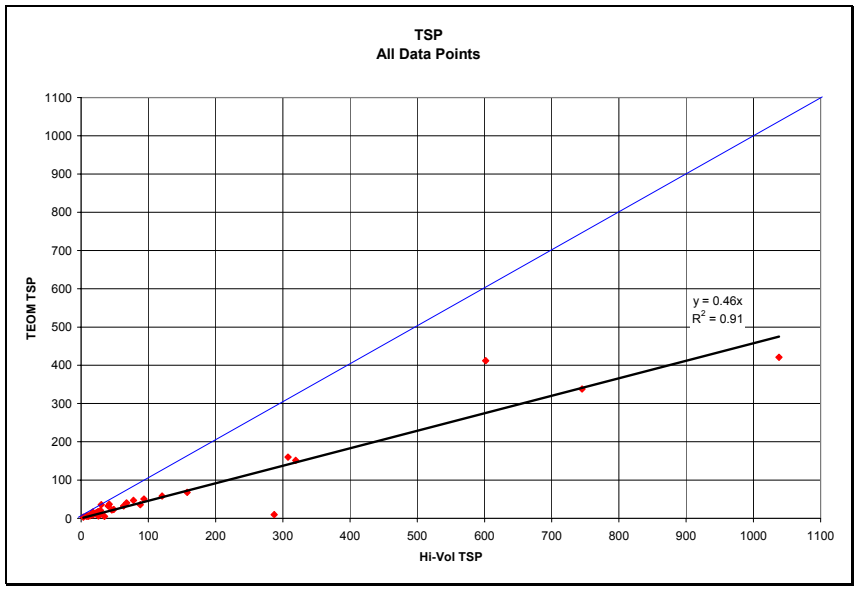

Figure 8: TSP All Data Points

Removing two outliers from the dataset increased the correlation coefficient to 0.99 and slightly changed the particle collection difference to 43% (Figure 9).

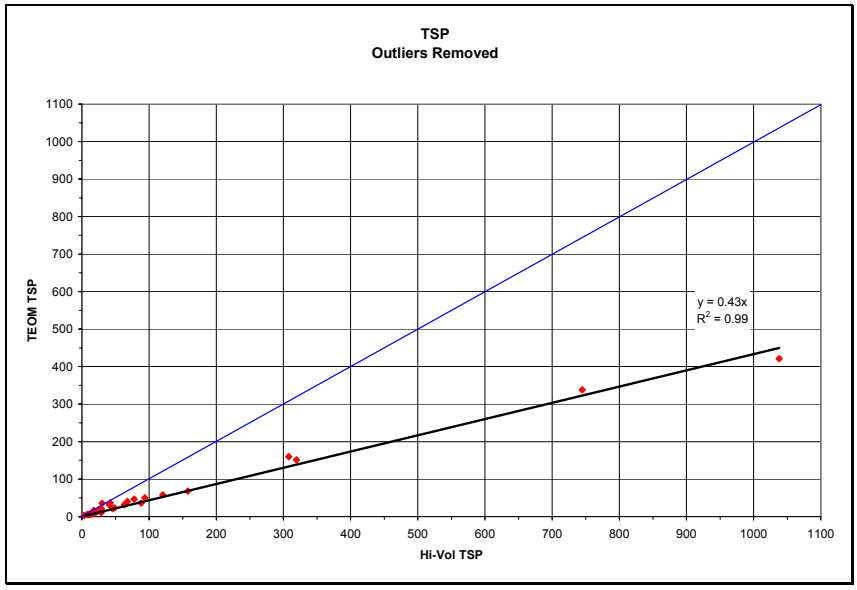

Figure 9: TSP Outliers Removed

There were only eight data points with a Hi-Vol TSP concentration greater than 100µg/m^3. Dropping out all values with a TSP greater than 100 µg/m^3 does significantly

change the particle collection difference. Using all values of less than 100 µg/m^3 the particle collection difference was 55% with a poor correlation coefficient of 0.77 (Figure 10).

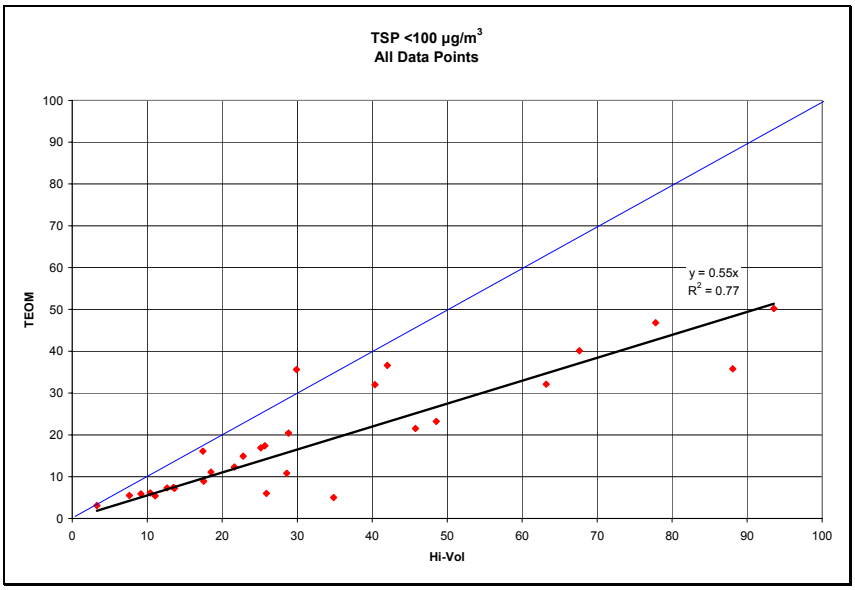

Figure 10: All TSP data points with a concentration less than 100 µg/m^3

By removing the outliers the correlation coefficient is increased to 0.97 and the particle collection difference is changed slightly to 56% (Figure 11).

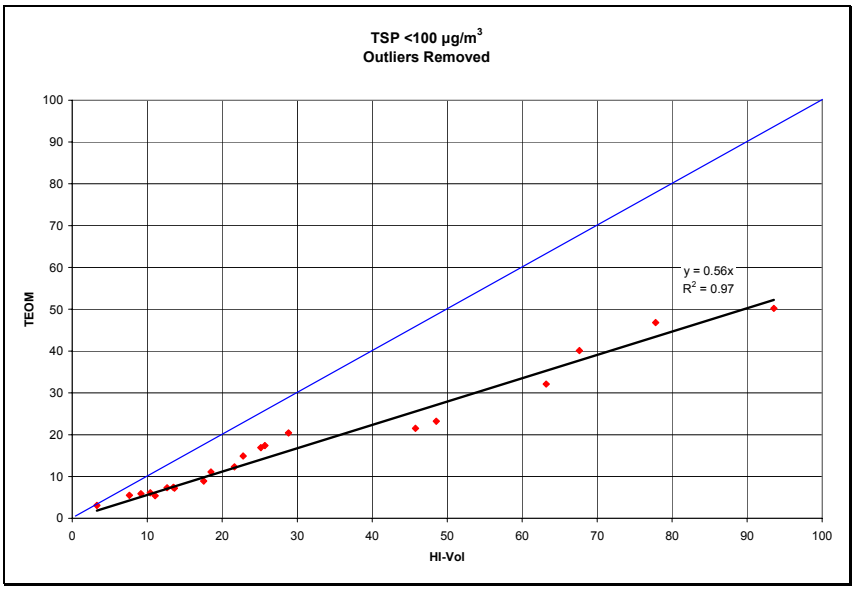

Figure 11: TSP data points with a concentration of less than 100 µg/m^3 and outliers removed.

Lead Comparison

Using all data points collected, a liner comparison of the Hi-Vol Lead concentration to the TEOM Lead concentration results in a particle collection difference of 15% with an unacceptably low correlation coefficient of 0.18 (Figure 12).

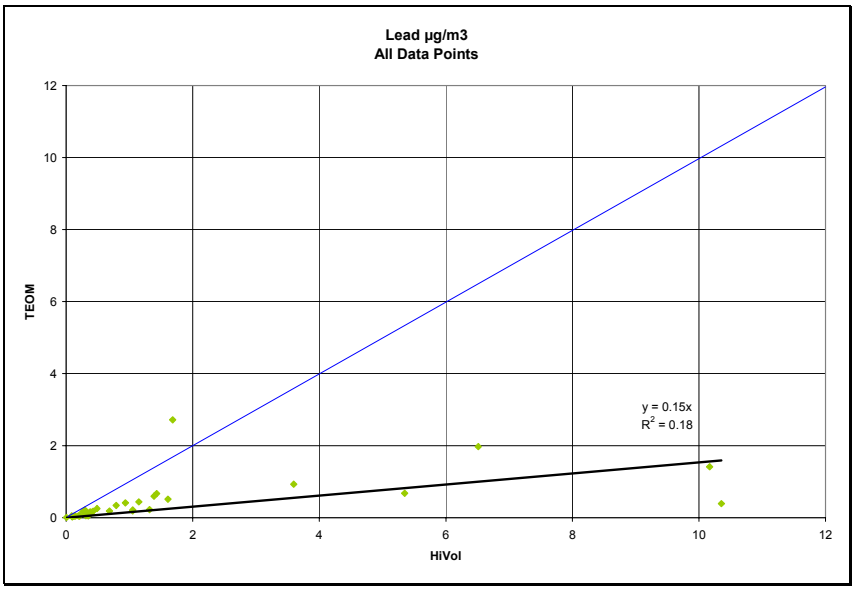

Figure 12: Lead all data points.

From review of the data, it appears that several of the Hi-Vol filters and one of the ACCU filters were contaminated during the handling process. Removing these outliers results in a particle collection difference of 42% with a correlation coefficient of 0.98 (Figure 13).

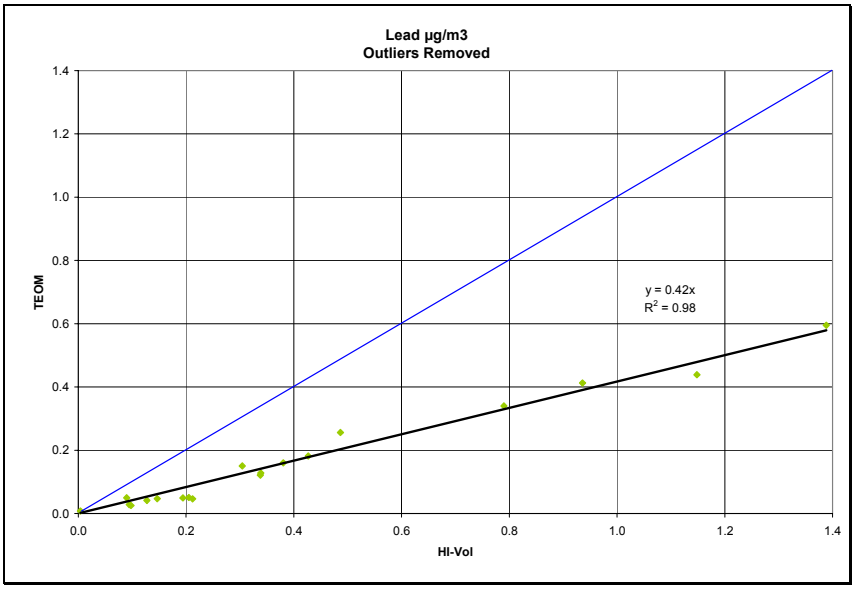

Figure 13: Lead outliers removed

Zinc Comparison

Using all data points collected, a liner comparison of the Hi-Vol Zinc concentration to the TEOM Zinc concentration results in a particle collection difference of 10% with an unacceptably low correlation coefficient of 0.30 (Figure 14).

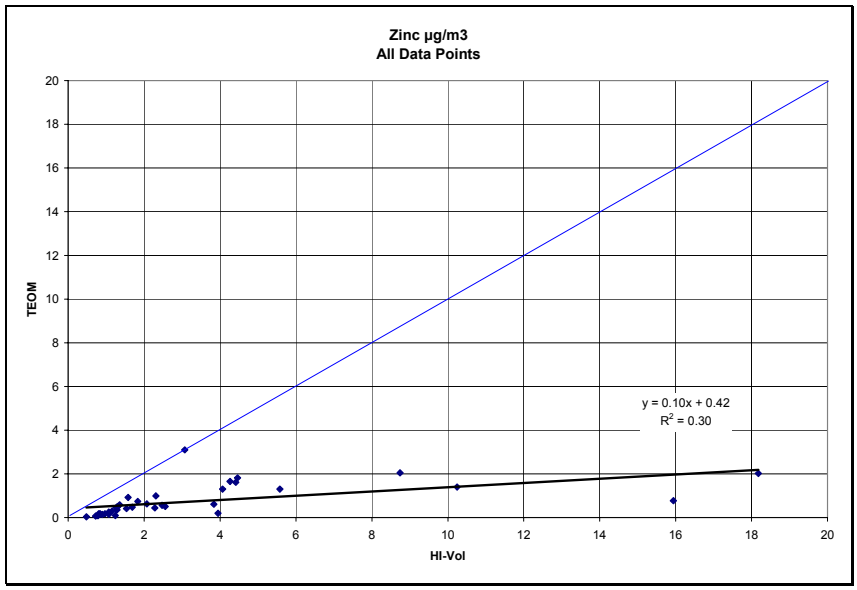

Figure 14: Zinc all data points

As with the lead is appears that several of the filters were contaminated. Removing the outliers, results in a particle collection difference of 42% with a correlation coefficient of 0.96 (Figure 15). The offset from zero on the Hi-Vol zinc concentration is due to zinc remaining on the filter from the manufacturing process. Unexposed filters analyzed for zinc contained approximately 0.6 mg/kg.

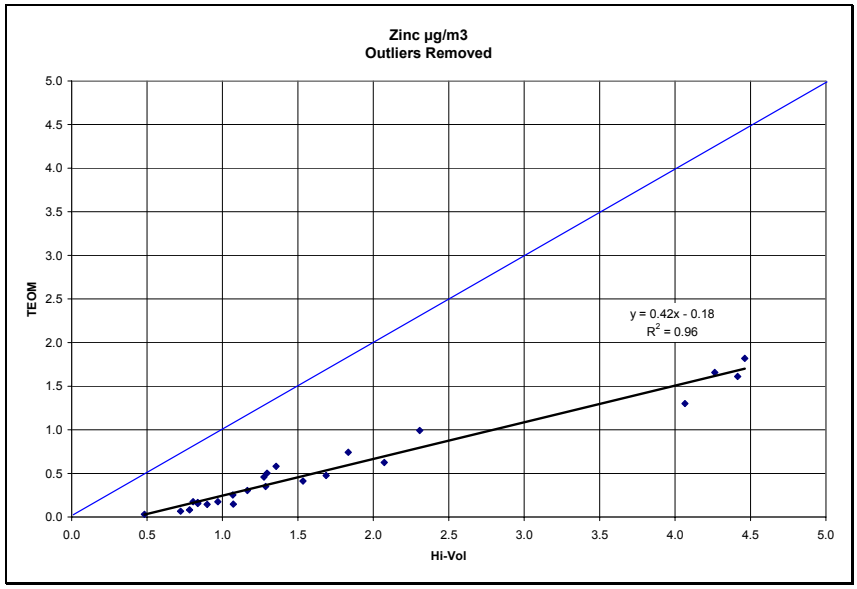

Figure 15: Zinc outliers removed

Particulate Collection Difference

After removing the outliers and accounting for the background level of zinc in the Hi-Vol filters the calculated particle collection difference for TSP, lead and zinc are similar.

$$\begin{aligned} \text{TEOM TSP} &= 0.43 * \text{Hi-Vol TSP} \\ \text{TEOM Lead} &= 0.42 * \text{Hi-Vol Lead} \\ \text{TEOM Zinc} &= (0.42 * \text{Hi-Vol Zinc}) - 0.18 \end{aligned}$$

The bimodal particle collection difference observed in the TDS data was not observed in the lead or zinc data. The data set did not contain a sufficient number of TSP values greater than 100 $\mu g/m^3$ to determine if there is a true bimodal collection efficiency of if it is related to the statistical manipulation of the data. For this analysis the observed bimodal collection efficiency is assumed to be related to statistical manipulation and the collection efficiency is linear.

The slightly lower collection efficiencies for the lead and zinc are related to the increased probability of sample contamination from the multiple handling steps required for the Hi-Vol filter analysis. To provide for a consistence comparison of the lead and TSP Hi-Vol concentrations collected at the Red Dog mine site in the early 1990s the TSP equation is recommended for the conversion of both the lead and TSP.

$$\text{TEOM Concentration} = 0.43 * \text{Hi-Vol Concentration}$$