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MEMORANDUM

TO: Deborah Pitt, Project Manager 38181
Faro Project Management Team

FROM: Dan Hrebenyk 5 February 2010

SUBJ: 2009 Air Quality Monitoring Program – Concerns about the Reliability of the Analytical results and Suggestions for Future Improvements

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This memorandum discusses the 2009 sampling protocol, Quality Assurance/Quality Control (QA/QC) issues with the 2009 analytical results as received from Maxxam Analytics Inc. for the PM_{10} and TSP samples collected during the 2009 sampling program, and recommendations for future monitoring. The results of QA/QC screening of Maxxam results by SENES indicate that there are some obviously inaccurate aspects to the data which, in our opinion, render the entire data set for 2009 unreliable. It is our opinion that the data should not be used for any future analyses. Our reasons for this opinion are outlined in the discussion of the results presented below.

The memorandum is presented in three main sections:

1) 2009 Sampling protocol describing how the data was collected and analysed;
2) QA/QC concerns with the Maxxam results;
3) Recommendations to prevent future problems in the monitoring program.

1.0 2009 SAMPLING PROTOCOL

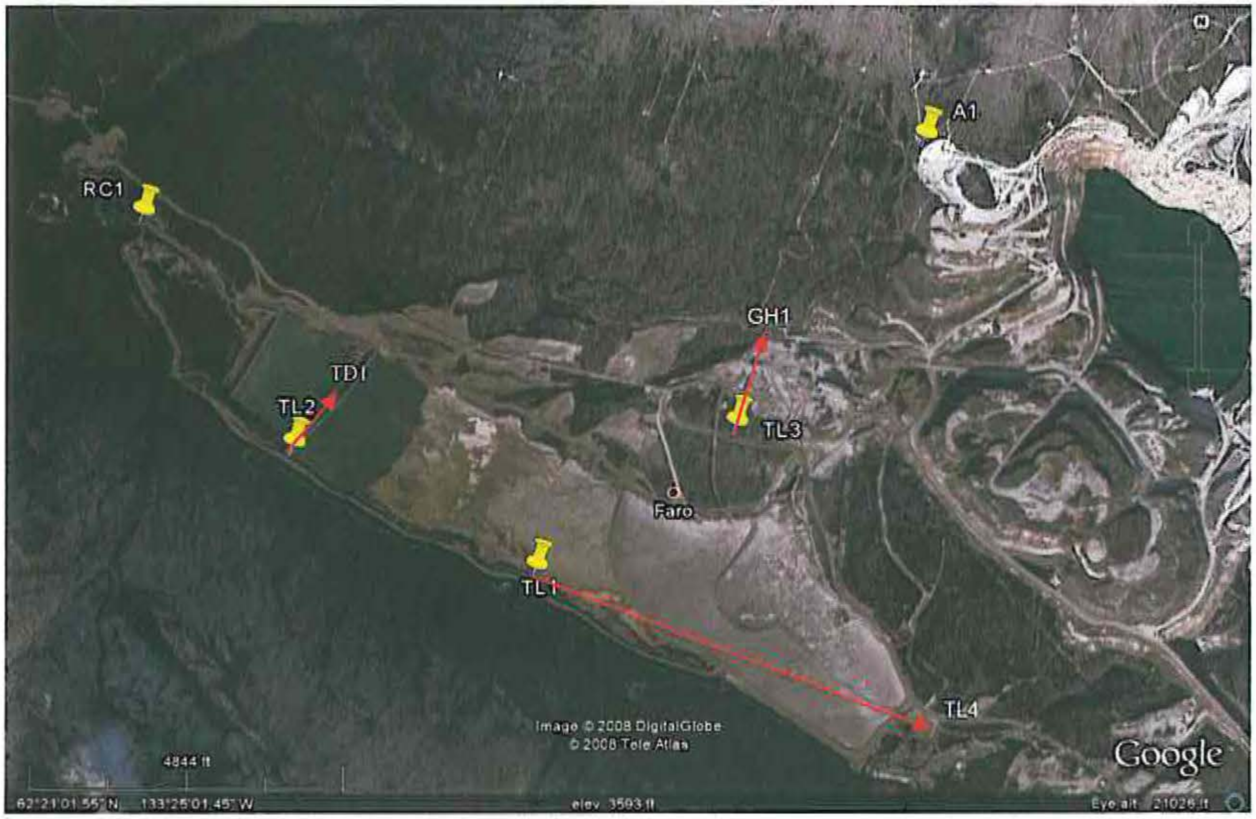
1.1 Changes to Sampling Locations in 2009

Figure 1 shows the location of the sampling sites at the Faro Mine Site used in the 2009 sampling program. Three of the sites were moved from their original locations in 2008. Site TL1 was moved to the eastern end of the tailings area (now referred to as TL4) because its original location was deemed to be too much on the edge of the tailings area to properly represent conditions around the tailings. In addition, there was an expectation of work to be done at this end of the tailings in 2009 and it was considered desirable to have a station at that location. Site TL2 was moved to the centre of the tailings dam in order to better capture fugitive dust from the tailings area, and was renamed TD1. Site TL3 was discontinued and the equipment was moved to a new location near the guard house (GH1) because this area has a lot of activity and it was deemed necessary to monitor particulate levels in this area. The data from TL1 and TL3 remain useful as benchmarks for future reference, but monitoring would be continued at the new locations in the future.

The other sampling sites at the Grum and Vangorda pits (VG1, VG2 and G1) and in the Faro townsite (FA1) remained unchanged from those used in the 2008 sampling program, except that the VG2 site was moved off the breach dam beside the effluent discharge pond between the Vangorda and Grum pits northward about 50 metres so as not to interfere with form in the immediate area of the discharge ponds.

In addition to the TSP and PM_{10} samples, a total of six monthly dustfall samples were collected during the months of July, August and September at sites TL4 and RC1.

Figure 1: Location of Sampling Sites at the Faro Mine Site



1.2 General Note on Methodology for Collecting Air Samples in 2008 vs. 2009

TSP and PM_{10} samples collected in 2009 used the same methodology that was used in 2008. Samples were collected at nine locations with paired TSP and PM_{10} samplers located at each site. Samples were collected using battery-operated Airmetrics Mini-Vol samplers. All but one of the samplers was the same as those used in 2008; the new sampler being one that replaced a sampler that went missing after the 2008 program. Three of the samplers were sent to Airmetrics for repair prior to being used in the 2009 program because they were found to be inoperative at the start of the 2009 program.

Samples were collected on 47 mm filters provided to the program by Maxxam. The filters received were pre-weighed by Maxxam and had filter identification numbers assigned to them by Maxxam. The filters were enclosed in individual filter holders that were ready to install into the Mini-Vol samplers. Therefore, filter handling was actually simpler than it had been during the 2008 program. All that the field staff had to do was place the filter holders into the sampler heads and record the filter ID numbers on the field data sheet. In order to ensure that the filter ID numbers were correctly recorded, an adhesive sticker with the filter number was attached to the outside of each sampler head prior to the heads being taken out to the field, and each pair of sampler heads was placed in individual, sealed plastic baggies for transport to the sampling locations. The process was reversed when the samples were retrieved.

Sampling was conducted every 6th day, starting on June 18th and ended on September 28th for a total of 18 sampling dates.

Field staff for the 2009 program was trained in the sampling procedures in the same way that staff were trained for the 2008 program. The exposed filters were shipped to the SENES office in Vancouver by courier in two batches. The exposed filters for each sampling date were packaged separately for each sampling date, and were not opened by SENES prior to shipping them to Maxxam. Filters were shipped to Maxxam after the field data sheet information of sampling dates and filter ID numbers were transferred to Chain of Custody forms provided by Maxxam.

1.3 Filter Sample Analysis Methodology

Exposed filters provided by SENES to Maxxam would have been weighed by Maxxam to obtain pre-exposure weight of the filters in order to determine the total particulate matter mass loading on each filter by subtracting the pre-exposure weight from the exposed filter weight. The filter samples would then have been analyzed using gas chromatography/mass spectrometry (GC/MS) to obtain the elemental composition (mass) on each filter. The GC/MS method is destructive in that the entire filter sample is used in the analysis such that the sample cannot be subsequently re-analyzed. Note that the filters used for the sampling program are Teflon filters (polytetrafluoroethylene or PTFE) which have very low elemental concentrations making them particularly suitable for use in sampling in low concentration environments.

The results of the analysis by Maxxam were provided to SENES as digital spreadsheets with the total PM mass and elemental composition (mass) of each filter by filter ID number. The data were provided to SENES as total mass/filter (i.e., μg/filter) for TSP, PM_{10} and for each element. SENES then used the sampler flow rate data recorded on the field data sheets and the temperature and atmospheric pressure recorded at the TL4 monitoring site to calculate the concentration of each parameter by combining the laboratory mass with the calculated volume of air that was sampled.

2.0 QA/QC CONCERNS WITH ANALYTICAL RESULTS FROM MAXXAM

2.1 Elemental Composition of PM_{10} and TSP Samples in 2009

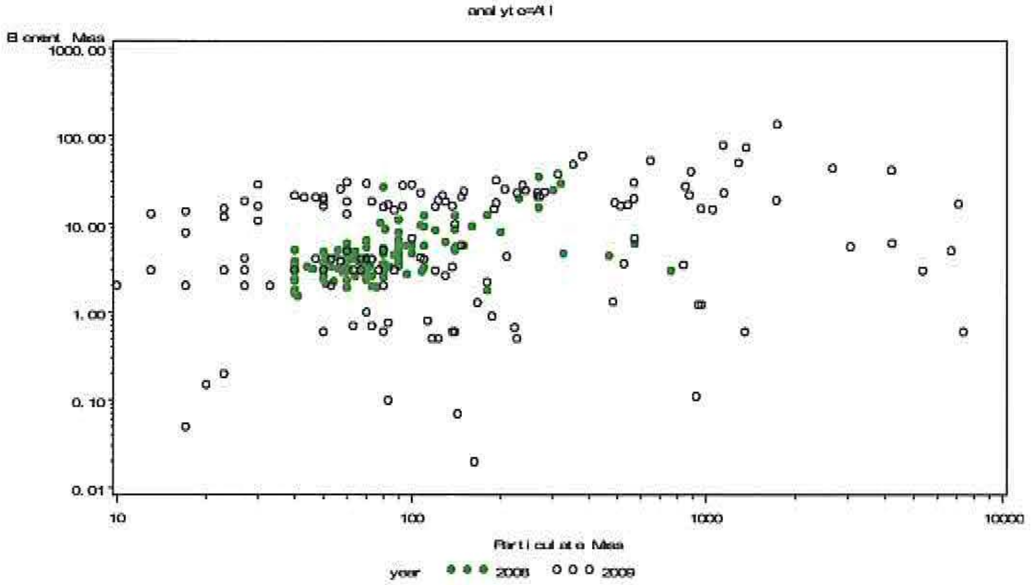
A QA/QC check was conducted to compare the elemental mass on the filter determined with ICPMS with the particulate mass determined from weighing the pre and post sample filters. Since Maxxam conducted both measurements, the expected relationship between these mass measurements can be compared as a QA/QC check focused on Maxxam analyses. This relationship was checked for internal consistency as well as with a comparison to the 2008 results.

The QA/QC check of the 2009 data indicated that there a much larger proportion of element masses reported as being below the MDL in 2009 as compared to 2008. This was largely because the Maxxam laboratory selected for the 2009 measurements by the Faro Mine Project used much higher MDLs than the 2008 laboratory for most elements. The initial QA/QC analyses considered only those elements and particulate masses that were both above the MDL for comparison of the relative masses. The total elemental mass on the filter was only based on the combinations of elements with above MDL measurements. This will tend to underestimate the Maxxam mass on the filter compared to the 2008 measurements.

Figure 1 shows a comparison between total measured elemental mass plotted against particulate mass for those filters with particulate mass above the MDL and the sum of those elements with measurable mass (reported above their respective MDLs). Both logarithmic and natural scale plots are provided. A correlation would be expected of increasing element mass with increasing particulate mass and this is generally apparent for 2008 which has few outliers. The 2009 data show much less correlation between elemental mass and particulate mass. Due to the higher MDLs for elements in 2009, the element mass is generally underestimated compared to the 2008 analyses.

Figure 2 shows a comparison between the element mass of a major crustal element (magnesium) and the particulate mass on the filter. The 2008 data show an expected correlation between magnesium mass and particulate mass. By comparison, the 2009 data shows more variation and less correlation than the 2008 data, and there appears to be a general discrepancy where the 2009 data show less element mass than anticipated for the reported analytical mass for those measurements with both elemental mass and particulate mass above the MDL. The very high particulate masses are unsupported by the measurement of magnesium, as was also apparent for the underestimated total elemental mass in Figure 1.

Figure 1: Comparison of Total Particulate Matter (PM) and Total Elemental Mass Reported for Samples Collected in 2008 and 2009



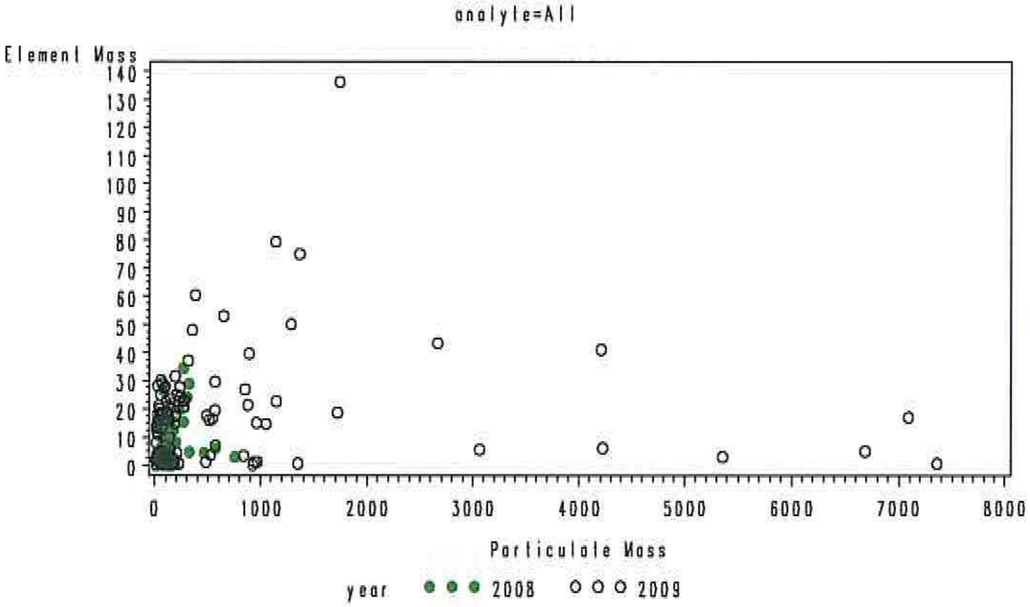
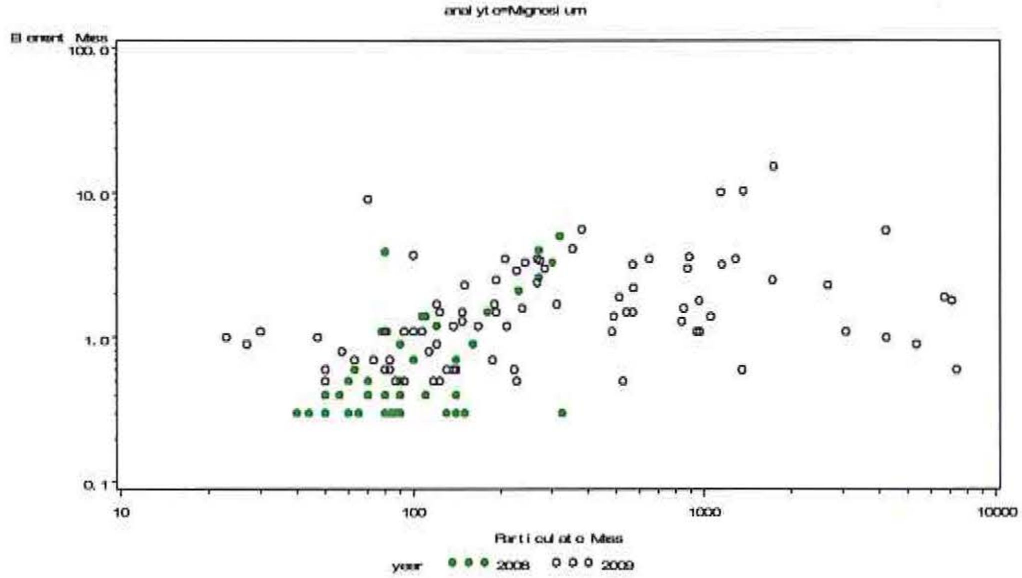


Figure 2

Comparison of Total Particulate Matter (PM) and Total Mass for Magnesium Reported for Samples Collected in 2008 and 2009



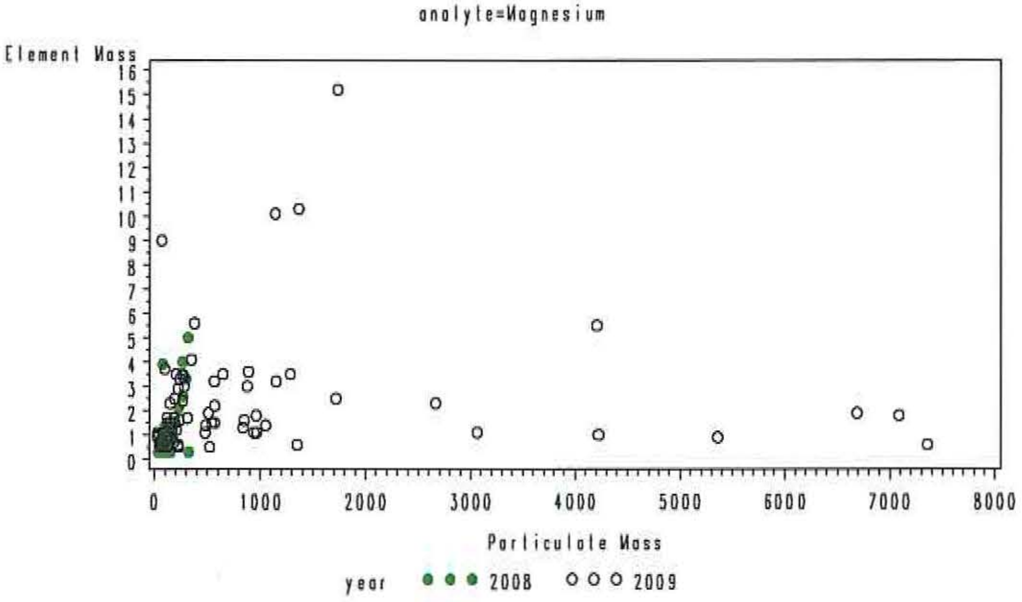


Table 1 below provides a summary of the distribution in the ratios of elemental mass to particulate mass for the 2008 and 2009 programs. The scatter in the 2009 data is apparent in the 5th and 95th percentiles of the ratio between elemental and particulate mass which are broader than in 2008, and a substantial proportion of the results are outside the 2008 range.

Table 1: Comparison of the Distribution of Elemental to PM Mass Ratios in 2008 and 2009

Analyte	Year	Number	Below 2008	5th Percentile Ratio (expressed as %)	Median Ratio (expressed as %)	95th Percentile Ratio (expressed as %)	Above 2008	Element > Particulate
All	2008	134	n/a	2.7	5.7	11	n/a	
All	2009	138	35%	0.075	6.1	53	35%	1%
Magnesium	2008	47	-n/a-	0.21	0.57	1.5	-n/a-	
Magnesium	2009	84	20%	0.028	0.69	3.3	9%	0

Note:
'Below 2008' means the 2009 ratio was below the 5th percentile from 2008
'Above 2008' means the 2009 ratio was above the 95th percentile from 2008

Typically, one would expect that the trace metal and major inorganic crustal elements would contribute on the order of 10% to the total PM mass on the filter with much of the particulate matter in nitrates, sulphates, carbon compounds and elements such as silica present in soil. . Larger ratios are suggestive of errors in either the data or analytical results. For example, in the 2008 sampling program, the 5th and 95th percentiles of the ratios for total elemental mass for all sample measurements (and using the MDL for samples with <MDL measurements) were 2.7 and 11% respectively, with a median of 5.7% of the total PM mass when considering those measurements where both the elemental mass and particulate masses were above the associated MDLs. This demonstrates consistency within the samples collected in 2008, as well as with what would normally be expected. For the 2009 sample data, there were numerous samples where the total measurable elemental mass exceeded the total PM mass on the filter for measurements reported as <10 µg.

In contrast to the samples collected in 2008, 46% of the samples analyzed by Maxxam in 2009 were reported to have a total elemental mass greater than 10% of the total PM mass. It is particularly striking when only one or two elements are reported to account for all of the PM mass in the sample (see rows in Table 2 highlighted in yellow). This would dramatically underestimate the elemental mass in this sample: the true elemental mass if all elemental masses exceeded the MDL would be much higher compared to the particulate mass. For example, the results appear to be completely ludicrous when the total elemental mass is reported to be almost 15 times higher than the total PM mass (see sample for site GH1 on July 30, 2009 highlighted in blue). The elemental mass was 148.3 µg, from 10 analytes above the MDL, compared with a particulate mass of < 10 µg. Since this was from the same filter, it indicates either analytical measurement problems or difficulties in tracking the filter identification between the measurement of particulate and elemental mass.

Table 2: 2009 Samples Where Total Elemental Mass Was Greater Than 10% of the Total PM Mass

Sampling Date	Filter ID	Location	Elemental Mass >10% of Total Particulate	Number of Elements >MDL
06/18/09	36226	VG1 PM10	82.4%	2
06/18/09	36231	TL4 PM10	221%	3
06/24/09	36381	TL4 TSP	17%	3
06/24/09	36419	TD1 TSP	47%	3
06/24/09	36418	TD1 PM10	13%	1
06/24/09	36384	GH1 TSP	68%	5
06/24/09	36383	GH1 PM10	30%	1
06/24/09	36385	A1 TSP	47%	1
06/24/09	36390	VG1 TSP	36%	2
06/24/09	36387	VG2 PM10	30%	4
06/30/09	36416	TL4 TSP	14%	8
06/30/09	36412	VG1 TSP	12%	6
07/06/09	36312	TL4 TSP	10%	6
07/06/09	36308	GH1 PM10	17%	6
07/12/09	36269	RC1 PM10	12%	0
07/12/09	36278	A1 PM10	10%	0
07/12/09	36235	FA1 TSP	17%	0
07/24/09	36287	TL4 TSP	12%	9
07/24/09	36255	RC1 TSP	192%	5
07/24/09	36245	VG1 PM10	13%	5
07/30/09	36260	TD1 TSP	418%	8
07/30/09	36259	TD1 PM10	195%	5
07/30/09	36264	RC1 TSP	737%	8
07/30/09	36265	GH1 TSP	1483%	10
07/30/09	36266	GH1 PM10	585%	8
07/30/09	36267	FA1 TSP	657%	7
07/30/09	36268	FA1 PM10	204%	4
08/11/09	36396	TD1 PM10	100%	1
08/11/09	36402	G1 PM10	20%	1
08/11/09	36404	FA1 PM10	20%	1
08/17/09	36332	TD1 PM10	22%	2
08/17/09	36324	FA1 PM10	11%	1
08/23/09	36351	TL4 TSP	101%	2
08/23/09	36359	GH1 TSP	43%	3
08/23/09	36360	GH1 PM10	23%	1
08/23/09	36363	G1 TSP	30%	1
08/29/09	36442	TD1 PM10	12%	1
08/29/09	36477	RC1 TSP	14%	3
08/29/09	36439	VG1 TSP	50%	3

Sampling Date	Filter ID	Location	Elemental Mass >10% of Total Particulate	Number of Elements >MDL
08/29/09	36440	VG1 PM10	53%	3
08/29/09	36469	G1 TSP	32%	3
08/29/09	36470	G1 PM10	54%	3
08/29/09	36479	FA1 TSP	166%	4
08/29/09	36480	FA1 PM10	30%	1
09/04/09	36437	TL4 TSP	12%	2
09/04/09	36438	TL4 PM10	40%	3
09/04/09	36455	G1 TSP	40%	1
09/04/09	36456	G1 PM10	44%	3
09/04/09	36454	GH1 PM10	25%	3
09/04/09	36451	VG2 TSP	65%	3
09/04/09	36449	FA1 TSP	20%	4
09/04/09	36450	FA1 PM10	40%	1
09/16/09	36505	GH1 TSP	37%	1
09/16/09	36506	GH1 PM10	20%	1
09/22/09	36468	TL4 PM10	20%	1
09/22/09	36532	RC1 PM10	100%	1
09/22/09	36533	GH1 TSP	12%	1
09/22/09	36535	A1 TSP	41%	2
09/28/09	36465	TL4 TSP	28%	5
09/28/09	36466	TL4 PM10	12%	5
09/28/09	36457	TD1 TSP	16%	5
09/28/09	36458	TD1 PM10	15%	5
09/28/09	36463	RC1 TSP	52%	3
09/28/09	36464	RC1 PM10	94%	5
09/28/09	36459	GH1 TSP	16%	7
09/28/09	36460	GH1 PM10	20%	5
09/28/09	36499	VG1 TSP	110%	1
09/28/09	36500	VG1 PM10	30%	1

Note:

Elemental mass based on summing only those analytes with mass above the MDL. The number is indicated in the column titled "Number of elements > MDL". These ratios underestimate the ratio of elemental mass to particulate mass.

Particulate mass assumed equal to the MDL if particulate mass was below the MDL.

Therefore, the elemental and particulate mass analysis for the 2009 sampling program suggests that there were more samples where the elemental loading was too low to be measured than there were in 2008, and conversely many samples where the elemental loading was too high to be credible. In our opinion, this points to errors in the analytical techniques used by Maxxam to determine the masses of elements or particulates or the proper matching of sample identification. Our conclusion is that the analytical results are unreliable and should not be used.

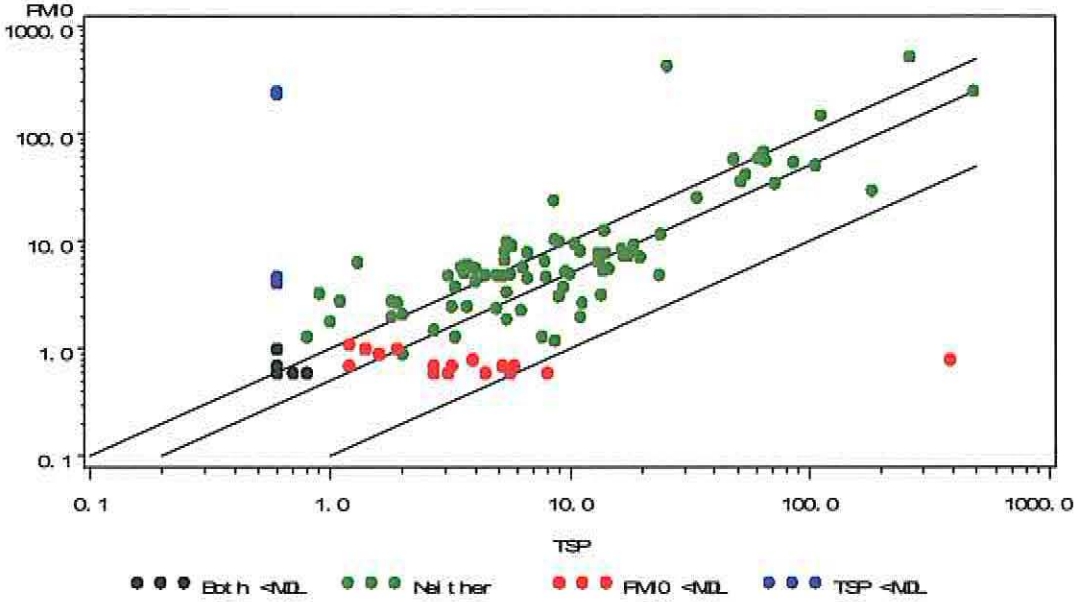
2.2 Comparison of PM_{10} and TSP Concentrations.

For the 2009 sampling program, most sampling locations had measurements of both TSP and PM_{10} at the same location and comparable times. Since PM_{10} is a component of TSP, the PM_{10} concentration (without consideration of measurement uncertainty) should never exceed the TSP concentration and may be substantially lower. Considering measurement uncertainty there is chance that PM_{10} might exceed TSP under conditions when there are no contributions to particulate from local sources. This could occur at low concentrations (i.e., $<10\ \mu g/m^3$) where the uncertainty in Mini-Vol samplers used in the sampling program have a relative accuracy of about $\pm 5\ \mu g/m^3$. For example, it is possible to have a pair of samples in which the TSP concentration was $5\ \mu g/m^3$ with a PM_{10} sample of $10\ \mu g/m^3$ simply due to sampling uncertainty. Pairs of measurements outside this range may be deemed to be implausible and likely contain an "outlier" due to measurement error.

Figure 3 shows the PM_{10} concentration plotted against the TSP concentration for samples collected in 2009. The lines on the plot indicate: 1) an upper bound estimate of perfect agreement (i.e., $PM_{10} = TSP$), 2) a typical average relationship (i.e., where $PM_{10} = 0.5 * TSP$) and 3) a lower bound estimate (i.e., $PM_{10} = 0.1 * TSP$). Points outside this range are possible outliers; however, measurement uncertainty needs to be considered to ascertain whether these are indeed outliers. The green symbols indicate that neither the PM_{10} nor the TSP mass particulate mass was below MDL. Some variation above the line of perfect agreement would be expected at lower concentrations due to the uncertainty in the measurement process. Substantial departures at higher concentrations (e.g., above $20\ \mu g/m^3$) indicate substantive discrepancies. A review of the data in Figure 3 suggests:

- 2009 measurements show correlation over a range of values as would be expected;
- quite a number of points in the 2009 samples are outside the range that would be expected to occur; and,
- there seem to be too many 2009 measurements just above the (upper) line of perfect agreement.

Figure 3: PM_{10} and TSP Concentrations



Notes:
'Both' indicates that PM_{10} and TSP are below the MDL; 'PM_{10}' indicates PM_{10} was below the MDL; 'TSP' indicates TSP was below the MDL; and 'Neither' indicates that PM_{10} and TSP were above MDL

Table 3 shows measurement pairs for the higher concentration measurements that were identified as outliers in the 2009 data set. The reasons for the outliers are unclear. . Moreover, the analytical results of the elemental analysis provided by Maxxam suggest that the errors are more likely to be related to errors in the analytical techniques used by the laboratory. These are discussed in the following section.

Table 3: Substantial Discrepancies Based on Comparison of PM_{10} and TSP

Sampling Location	Sampling Date	Estimated Concentration ($\mu g/m^3$)	
		PM_{10}	TSP
GH1	12-Jul-09	237.6	<0.6
TD1	12-Jul-09	521.3	262.1
RC1	12-Jul-09	<0.8	385.9
FA1	24-Jul-09	148.5	111.5
RC1	30-Jul-09	247.3	<0.6
TL4	30-Jul-09	429.7	25.3
VG2	5-Aug-09	58.7	48.2
TL4	28-Sep-09	24.2	8.5

2.3 Combined Mass Ratio and PM_{10} vs TSP Comparison

The combination of discrepancies in particulate versus elemental mass and the differences between PM_{10} and TSP could be explored on one of the measurement days. Table 4 shows a comparison for samples collected on 30 July 2009. The QA/QC review indicates that VG1 and VG2 samples are reasonable since TSP is about twice the PM_{10} and the mass ratios for both TSP and PM_{10} correspond to the range measured in 2008. The FA1, GH1, RC1 and TD1 results are unreliable due to the 'Exceeds" condition where the measureable elemental mass substantially exceeding the particulate mass on these samples (except for PM_{10} at RC1 where the ratio in the sample is denoted as "Under" since the ratio is below the 5th percentile from 2008). One would expect that concentrations would be elevated at all locations since this was a day affected by smoke from forest fires and particulate matter mass below MDL should not have occurred. This demonstrates the internal incompatibility of elemental and particulate mass for the Maxxam results on a large number of samples potentially occurring due to inconsistencies in filter identification tracking within the laboratory. Other samples indicate that the mass ratios are low ('Under') compared to the 2008 experience: this may be due to, in part, the underestimation of element mass based on the MDLs in 2009 or may reflect quality problems.

Table 4: QA/QC of July 30, 2009 Sample Data

Location	TSP Mass Ratio	TSP Concentration ($\mu g/m^3$)	PM_{10} Concentration ($\mu g/m^3$)	PM_{10} Mass Ratio
A1	1% (Under)	33.8	25.6	0% (Under)
FA1	657% (Exceeds)	< 0.7	< 0.6	204% (Exceeds)
GH1	1483% (Exceeds)	< 0.6	< 0.6	585% (Exceeds)
RC1	737% (Exceeds)	< 0.6	247.3	1% (Under)
TD1	418% (Exceeds)	< 0.6	< 0.7	195% (Exceeds)
TL4	10%	25.3	429.7	0% (Under)
VG1	7%	71.6	34.9	3%
VG2	8%	51.6	36.3	5%

Note:
'Under' indicates that the ratio between measurable elemental mass and the particulate mass is lower than the 5th percentile of the 2008 data.
"Exceeds" indicates that measurable mass exceeds the measured particulate mass in the sample.

2.4 Dustfall Measurements

Six dustfall jars from two different locations were shipped to Maxxam for analyses. Results of both particulate matter mass and elemental composition were only provided for the first two samples collected in July, but only the total particulate mass was reported for the four subsequent samples collected in August and September. Follow-up of this concern by SENES with Maxxam determined that the samples were no longer available for elemental analysis to be performed. This could be consistent with sample tracking problems at the laboratory.

3.0 RECOMMENDATIONS FOR FUTURE PROGRAMS

Based on the QA/QC screening analysis of the Maxxam results discussed above, SENES has concluded that the results of the entire 2009 sampling program are currently unreliable and should be disregarded. The major difference between the 2008 and 2009 sampling programs was that the 2008 filter samples were sent to Cantest laboratories while the 2009 samples were sent to Maxxam Analytics Inc.

Since the 2008 sampling program was successful in producing consistent and reasonable results, SENES does not believe that there are any changes required to the design of the sampling program itself for the 2010 sampling season.

Because the 2009 Maxxam analytical results are inconsistent relative to there internal control (e.g., Maxxam elemental mass does not coincide well with Maxxam particulate mass for the same filter), SENES recommends that efforts be made to review those procedures with Maxxam in order to better understand the source of those errors. If the review cannot successfully identify the reasons for the disparities in the analytical results that have been noted in this memorandum, SENES would recommend switching to another laboratory for the 2010 sampling program. It should be noted that Maxxam acquired Cantest on October 19, 2009. Therefore, if the problems with Maxxam cannot be resolved, future analyses could be conducted at Cantest, but only if the analyses were conducted using the same protocols and internal management programs that were used in 2008. SENES therefore recommends conferring with Maxxam about the information contained in the memorandum before proceeding with plans for the 2010 sampling program.

The selection of a suitable laboratory for filter analysis is a critical first step to correcting the problems that occurred in the 2009 sampling program. The laboratory that is chosen must be able to demonstrate that they can achieve method detection limits that are appropriate to this sampling program and laboratory certification by a recognized body for the key analytes of interest. To that end, the 2008 sampling program may provide a suitable benchmark of the required MDLs. Therefore, the MDLs listed in the report for the 2008 sampling program could be used as a suitable starting point for discussion with Maxxam and/or any other laboratory that might be considered for the future.

An enhanced quality assurance plan could be initiated for the 2010 program which would include accelerated delivery of samples to the laboratory and QA/QC review to access the reliability of field results as soon as reasonable possible. This may include some replicate sampling (e.g., 5% or less) where samples are provided as "blind" field replicates to the selected laboratory, and or, a secondary laboratory. There may be some benefit in ensuring laboratory reliability by conducting an inter-laboratory comparison study of the selected laboratories, including possibly Maxxam if the discrepancies are addressed, with a "gold standard" laboratory for samples collected in March or April, with possibly three samples per laboratory. This would allow for quantitative assessment of the selected laboratory in May prior to the beginning of field operations.

Lastly, prior to the 2010 sampling program, SENES recommends that all of the samplers be removed from the mine site and returned to SENES for re-calibration and to make sure that all are in good working order before being returned to the mine site. Sufficient time would have to be made to ship the samplers out from the mine, for QA/QC checks by SENES, and for the return of the samplers to the mine. SENES would recommend that a minimum of six weeks be allowed for this to occur prior to the start of any sampling. This would mean that the equipment would have to be shipped from the mine to SENES in early May in order to allow the sampling program to begin in mid-to-late June.