The IAEA/ RCA Fine and Coarse Particle Ambient Air Database

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Introduction

This final report accompanies the current IAEA/ RCA database from the 14 country Project RAC/07/015, "CHARACTERIZATION AND SOURCE IDENTIFICATION OF PARTICULATE AIR POLLUTION IN THE ASIA REGION". It fulfils the obligation under an IAEA contract to provide a fine and coarse ambient air database with explanatory notes by 30 November 2010 to the IAEA.

This database has been assemble from data provided by each of 14 RCA member states on fine particulate matter with aerodynamic diameter less than 2.5 µm (PM2.5) and coarse particulate matter (2.5 µm to 10 µm). The sum of the fine and coarse fractions gives the standard PM10 fraction (particles with diameters less than 10µm). The 14 countries providing more than 12 months of data include (in alphabetical order), Australia (AUS), Bangladesh (BAN), China (CHN), India (IND), Indonesia (INO), Korea (KOR), Malaysia (MAL), Mongolia (MON), New Zealand, (NZ) Pakistan (PAK), Philippines (PHI), Sri Lanka (SRI), Thailand (THA) and Vietnam (VIE).

Each country was provided with the same fully characterised GENT sampling unit [1] and the same reflectometer unit to measure black carbon (BC). All 14 countries sampled at one or more sites covering the period from May 2000 to December 2009. This provided local, regional and even global information so both short and long range transport could be studied. The GENT sampler is a stacked filter system with 47 mm diameter fine and coarse Nuclepore (polycarbonate) filters providing mass information on the two different size fractions making up the PM10 particulate matter. Each of these filters, where possible, were analyse by the country in which they were collected. If this was not possible then other member states with extra analytical capacity performed this task. Analytical methods include, ion beam analysis (IBA), particle induced X-ray emission (PIXE), particle induced gamma ray emission (PIGE), particle elastic scattering (PESA), instrumental neutron activation analysis (INAA) and X-ray fluorescence (XRF). The sites, their locations, their types, descriptions and known particulate sources together with the analytical techniques used are summarised for each country in Appendix 1.

Several countries have already published fine and coarse data, including ambient air masses, compositions and elemental concentrations. Some have taken this further and looked at source fingerprinting, source apportionment and even identified long range transport of both natural and anthropogenic pollutants within and across countries.

It is not the purpose of this document to report on the interpretation of data within this dataset such as sources or source fingerprints. This has been done by many individual countries and published in the many journal publications list below in the reference section [1-95].

Here we just describe what is in this IAEA/ RCA database and how it was obtained and identify the typical range of fine and coarse mass fractions and the key 20 or so elements that occur on each filter.

What Should a Good Data Base Look Like?

At previous RCA meetings it was generally agreed that the current RCA database for this Project should have the following attributes:-

- All 14 RCA member states have only quality data included in database. Lower quality data should be clearly identified.
- The common database should span at least 5 complete years between 2002 to 2007 inclusive, for each member state.
- The database should contain at least three continuous years at the one site from each member state.
- The database should contain at least 300 fine and 300 coarse filters (2 per week for 3 years) for each member state.
- Every filter has been analysed for at least fine and coarse mass, black carbon, silicon (or aluminium) and sulfur (for soil and sulfate transboundary studies).
- Each member state has applied nuclear techniques to obtain at least 15 different elemental concentrations for each filter (so source apportionment can be performed/ compared across member states).

The IAEA/ RC Fine and Coarse Particulate Matter Database

As of the 30 November 2010 the database contained 8 worksheets with sampling data for 8,831 days for fine and coarse filters between May 2000 and December 2009. The first three worksheets contain the concentrations, errors and minimum detectable limits (MDLs) for the fine particles, the next three worksheets contain the corresponding data for the coarse particles (2.5 µm-10 µm) and the last two are the known problems and know errors associated with each country's dataset. Site locations, descriptions and nuclear techniques used are summarised in Appendix 1, Table A1.

All data were obtained under the following standard operating conditions:-

- Sampling using GENT samplers (Hopke et al 1997) over a 24 hr period once or twice a week.
- Typical flow rates in the GENT stacked filter system were nominally supposed to be16 l/min.
- Fine filters measured for black carbon (BC) using the Smoke Stained Reflectometry method with an assumed mass absorption coefficient (ε m^2/g) given in Table A2 for each member country. This generally ranged from 5 m^2/g to 10 m^2/g. This depends critically on average BC particle size and should really only be applied to the BC fine fraction as mass absorption coefficients are strongly varying with particle sizes above 2 µm and fall off quickly with values well below 3 m^2/g for the larger size fractions [8].

The EXCEL database '***IAEAGENTDataallcountries30Nov10.xls'*** is about 20 MB in size and contains 8 separate worksheets. In each worksheet the 1st row contains the column label, the 2nd row the atomic number of the elemental species measured and the 3rd row the type of worksheet (Conc, Error or MDL). The columns in each worksheet contain the measured data.

Elements from fluorine (Z=9) to uranium (Z=92) have been considered with different countries analysing for a different range of elements depending on their access to given techniques. The first 22 elements from F to BC were the most common ones analysed for across the majority of countries. The remainder from Sc to U were not as commonly used and so were separated out. The remaining four columns were for estimates of the soil, reconstructed mass, country symbol and number of elements analysed on that sampling day and are discussed in more detail below.

The order and labelling of these columns in all the current worksheets should not be changed under any conditions as standard scripts and macros used to generate this dataset expect to find certain data in their currently defined columns within each worksheet and will not run if they are move or changed. This is most important, the data coordinator will not accept any new data for inclusion into the current data set if it does not strictly conform to the current format.

The worksheets and their symbols and labelling should be self evident. Below is a short description of what is contained in each of these worksheets.

CONCFine Worksheet

This worksheet contains at least 70 columns in a standard format and should not be changed. Columns 1-9 [A-I] contain the SiteID, the Day, the Month, the Year, the sample site name, the total exposed volume (m^3) collected, an error code (0-9), the sampling date and the total gravimetrical measured fine mass divided by the total sampled volume (ng/m^3).

Columns 10-70 [J-BR] contained the measured elemental data from fluorine (F) to uranium (U) followed by the estimated *Soil* content, the reconstructed mass (RCM) the three letter country code and the number of different elements measured by the participating country. All concentrations are in (ng/m^3). An error code Err=0 implies no known problems with this data line and an Err=9 implies this data line has significant known problems (low flow rates, not run for required time, damaged filters etc..) and should not be included in any general analysis of the data.

The elemental data in this worksheet can be used to make estimates of a range of pseudo chemical species in the standard way [3-5]. Some of the species are defined in Equs. (1) to (10) below. The Soil and RCM concentration columns in this worksheet are defined from other columns in the spreadsheet by the Equs. (3) and (6) below.:

Salt = 2.54[Na] (1)

Ammonium Sulfate = 4.125[S] (2)

Soil = 2.20[Al] + 2.49[Si] + 1.63[Ca] + 1.94[Ti] + 2.42[Fe] (3)

Smoke = [K] – 0.6 [Fe] (4)

Organics = 11([H] – 0.25[S]) (5)

RCM = Salt+ Ammonium Sulfate+ Soil+ Smoke+ Organics+ BC+ traces (6)

NonseasaltSulfur = S – 0.08[Na] (7)

$Error^2 = Calib^2 + Expt^2 + Stats^2 + \ldots\ldots$ (8)

$MDL = 3\ (Bkg)^{1/2}$ (9)

S/N = Conc/ MDL (10)

where the square brackets [..] represents the concentration (ng/m^3) of that element in the spreadsheet. Equ (2) assumes all the sulfate is fully neutralised and occurs on the filters as ammonium sulfate. Soil, equ. (3), was estimated from the oxide form of five major elements, Al, Si, Ca, Ti and Fe. The organic matter estimate, Equ. (5), assumes the average $PM_{2.5}$ organic composition was 9%H, 20%O and 71%C [3-5]. The non sea salt sulfur, Equ. (7), assumes the [S/Na] ratio of 0.08 for sea salt aerosol.

Note Organics, Equ. (5), are generally estimated in this database from hydrogen [H] cannot generally be well measured on Nuclepore filters as they are composed of H, C and O themselves. Hence the term Organics in the (RCM) is set to zero for all filters using the GENT samplers. This means the average RCM will be significantly reduced as the average Organic content of fine filters can be between 10% and 40% of the total fine gravimetric mass.

Soil can be used to represent an estimate of the fine or coarse windblown soil present in ambient air. Equ. (3) assumes that the majority of the 5 elements used to make this estimate come from airborne soils alone and there are no other major source contributions. This may not always be true for example in the present of significant cement works Ca concentrations maybe high. In the presence of large metals foundries Fe maybe large as well. Under these conditions the airborne Soil estimates from Equ. (3) would be overestimated, so this estimate should be used with caution and a recognition of its limitations.

The reconstructed mass (RCM) estimate is an attempted to determine how well a particular concentration analysis measures most key chemical species present. Ideally if this sum is close to 100% of the gravimetric mass then we have determined most chemical species present. That situation would be 100% mass closure. Most datasets of this type produce mass closures above 40% as not all species are determined, however they are still ideal for source apportionment techniques like positive matrix factorisation (PMF) if the elements measured adequately span each of the known sources present.

The total error estimates associated with this dataset have been calculated by adding individual error estimates in quadrature as shown in Equ. (8) above. Generally there were at least three components to this error estimate, the measurement calibration errors (Calib), the experimental measurement errors (Expt) and the statistical counting errors (Stats). As a guide these three component errors might be ±5%, ±10% and

±1% to 30% for example. The minimum detectable limit (MDL) for any given elemental measurement was estimated from the background area (Bkg) under the peak representing that element via Equ. (9). The signal to noise ratio (S/N) is a parameter often used in source apportionment studies and can be calculated from Equs. (9) and (10). It is a useful parameter to determine the significance of any single elemental concentration estimate and whether or not it should be used in a PMF analysis for example.

ErrFine Worksheet

This fine particle error worksheet should have a 1-1 correspondence with the fine particle mass worksheet CONCFine. The main differences being in the first 4 columns which are the SiteID, the sampling date and the fine particle mass error. The measured elemental fine errors for the elements F to U, Soil and RCM are given in (ng/m^3) and are directly related to the measured fine mass concentrations given in the worksheet *CONCFine*. These errors included the system calibration errors, the experimental measurement errors and the statistical counting errors (all added in quadrature, Equ. (11)). They are ideal for use in positive matrix factorisation (PMF) codes and chemical mass balance (CMB) calculations used for source fingerprinting and apportionment studies.

Unfortunately not all countries have completed all columns and rows for error estimates. This can be overcome to some extent by taking the mean or median values for that country for each element or column and using that for the missing data from that country within that column.

MDLFine Worksheet

The minimum detectable limit (MDL) worksheet contains the experimental minimum mass concentrations estimates for each of the measured elemental species in (ng/m^3). They represent values of the order of 3 standard deviations above the background under any peaks used to determine the corresponding elemental concentrations, see Equ. (9). There must also be a 1-1 correspondence between this worksheet and the *CONCFine* and *ErrFine* worksheets.

As with the Error Worksheet not all countries have completed all columns and rows for MDL estimates. This can be overcome to some extent by taking the mean or median values for that country for each element or column and using that for the missing data from that country within that column.

CONCCoarse Worksheet

This worksheet has an identical format to the CONCFine worksheet but all data are for coarse (2.5 µm-10 µm) particles. The cell by cell correspondence of this worksheet with the CONCFine worksheet should not be changed or altered in anyway.

ErrCoarse Worksheet

This worksheet has an identical format to the ErrFine worksheet but all data are for coarse (2.5-10µm) particles. The cell by cell correspondence of this worksheet with the CONCFine worksheet should not be changed or altered in anyway.

MDLCourse Worksheet

This worksheet has an identical format to the MDLFine worksheet but all data are for coarse (2.5-10µm) particles. The cell by cell correspondence of this worksheet with the CONCFine worksheet should not be changed or altered in anyway.

Problems Worksheet

This worksheet contains a list of know identified problems with each country's dataset and should be read in conjunction with the dataset and all worksheets before data is used in any external application or quoted externally. In some cases the causes of these problems are unknown and the data should therefore be used only with great caution. Where problems have been identified an error code Err=9 has been placed in the Error column against that sampling day.

Errors Worksheet

This worksheet contains the output of a software scan of each country's dataset and locates problems found with individual data lines. It lists a country, its original data input file and date and then a one line summary of the number of CONCFine, ERRFine, MDLFine, CONCCoarse, ERRCoarse, MDLCoarse entries in the dataset for each participating country. If there are any errors found they are then listed under each country with the “LINE=number” for which the error occurs. Where errors have been identified an error code Err=9 has been placed in the Err column against that sampling day.

Dataset Inputs

A summary of each participating country’s dataset inputs are given in the Tables of Appendix 2 for fine and coarse filters from the GENT sampler at each of the sites. Note some countries have run two or more sampling sites during the study period and hence have more than one line entry in the Tables of this Appendix. This Appendix contains the start and stop dates for sampling, the number of days which have error codes Err=9, the number of days with mass, Al, Si, S and BC measurements above zero. This is followed by the number of days with BC errors (BCErr>0), BC MDL (BCMDL>0) and number of measured elements (Elts>0) greater than zero. Finally the last column is the minimum and maximum number of elements analysed in that country’s dataset.

Zero entries (in red) in this Table show possible problem areas for the dataset. Ideally all entries should be close to or the same as the Mass>0 entries in column 5 of this Table for a complete dataset for each country.

The tables of Appendix 2 show that 12% of the fine data and 18% of the coarse data have errors Err=9. That is 88% of the fine and 82% of the coarse data presented in this dataset is probably ‘good’ data. This is a respectable error rate for this type of project involving 14 different countries sampling at least once a week for more than 5 years. I believe there could be some issues with countries with error rates significantly below the average.

At least 97% of the fine data and 94% of the coarse data have been analysed for either Al or Si which means good airborne *Soil* estimates may be made for the vast majority of data using Equ. (3) above. This is ideal for the study of long range transport of soil between and across countries within the Asian study region.

Each member state was supplied with a reflectometer system for measuring fine black carbon (BC), so it was encouraging that 93% of the fine dataset contained BC measurements. The coarse data contained only 67% BC measurements, but this was not an issue as black carbon dominates in the fine fraction and it is not clear what is the appropriate mass attenuation coefficient to use for coarse particles anyway.

Sulfur is a main component of anthropogenic fine particle pollution, it occurs from combustion of coal, oil and motor vehicles. 78% of the fine data and 66% of the coarse data analyses measured sulfur. The main problem countries being China and Korea for the fine fraction and China, Korea and Sri Lanka for the course fractions. These countries relied heavily on INAA results which are not ideal for determining total sulfur levels.

The maximum number of elements analysed for by each country on each filter (fine or coarse) ranged from 17 to 40 so the dataset generally has a large potential for source apportionment studies where typically only 10 or more elements might be needed. Furthermore the range of elements used spans most commonly occurring sources of fine and coarse particles so this is another positive aspect of this unique database.

Fig. 1 shows a plot of the start and stop sampling dates for each site and each member country. It clearly shows that, for at least one site in each member state, the current data set spans the 5 year period 2003-2007 inclusive for many of the 14 participating countries. Several countries have more than one site operational during the study period. This was not necessarily a good thing, the ideal situation was to be sampling at the one site the whole time. We did however ask people to try and obtain data from one rural and one urban or industrial site as defined on the site summaries in Appendix 1. If there was only one GENT sampler available then this meant that it had to be moved from site to site and hence these sampling times could not overlap. Several countries did managed to operate more than one sampler at the same time and hence had overlapping data at more than one site as demonstrated in Fig. 1 (see AUS, CHN, INO, KOR, SRI and THA for example).

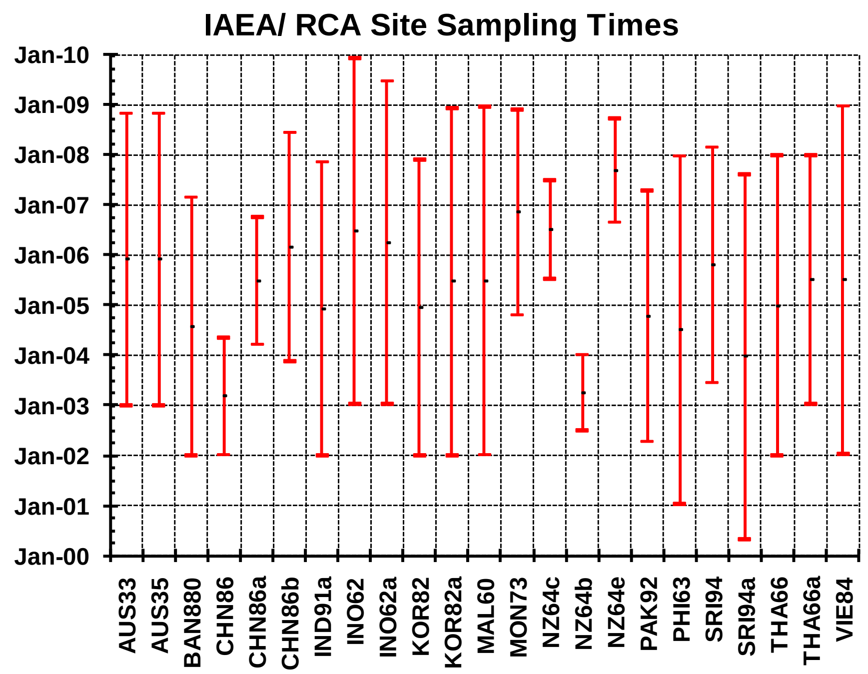

Fig. 1. Timeframe for each site spanned by the current dataset as of 30 November 2010. The numbers at the end of each country label on the x-axis represent the internal country sampling site numbers or if they had none their country phone code (with a letter a, b, c ...) was used to distinguish different rural and urban sites in the same country.

Fig. 2 shows the number of fine plus coarse filters analysed for mass for each site in each country. All countries except Malaysia have 300 fine filters and 300 coarse filters or more for one site or more exposed and measured mass during the study period from May 2000 to December 2009.

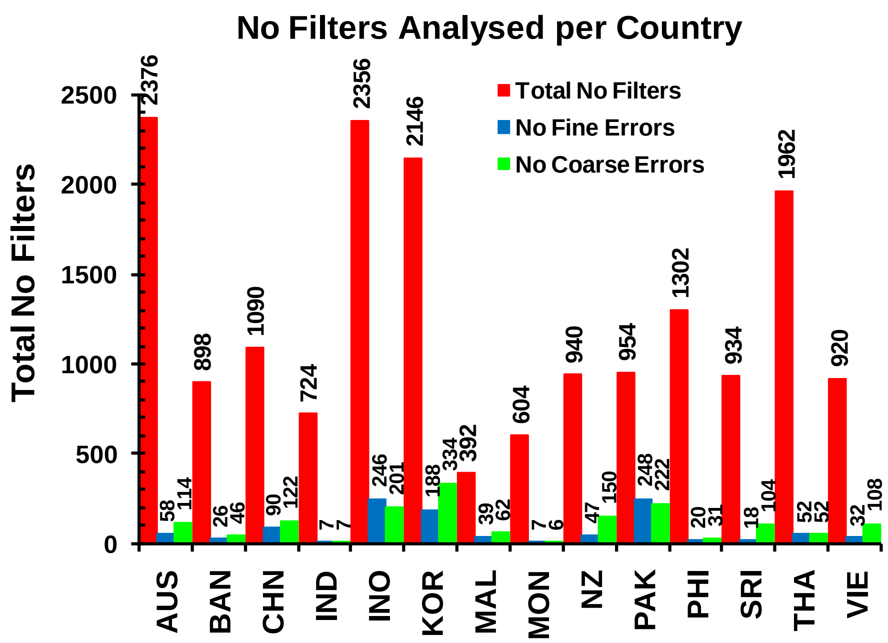

Fig. 2. Total number of fine plus coarse filters analysed per country between May 2000 and December 2009. The errors represent the total number of fine (blue) and coarse (green) filters with error code Err=9 in the dataset.

There were a total of 8,831 fine and 8,831 coarse filters measured in all with 1,068 (12%) fine filter errors and 1,559 (18%) coarse filter errors The errors represent the total number of fine (blue) and coarse (green) filters with error code Err=9 in the dataset. There are more than enough filters collected by member countries to perform positive matrix factorisation for source apportionment studies provided all of these have been analysed for 10 or more different chemical species.

Ideally each GENT sampling unit should run at around 16 l/min to produce the desired fine and coarse cutoffs. For a 24 hour sampling period this would mean a total volume of ambient air collected of around 23m^3, which is typical of the amount of air an average human being may breathe in a day. However, many sites were sufficiently heavily loaded with ambient fine particle pollution that continuous operation of a GENT unit for 24 hours was not possible without clogging. To overcome this various sampling regimes were used with some countries running for a total of 6, 8 or 12 hours a day instead of the full 24 hours. This produced different total volumes collected by various countries during the sampling period.

Fig. 3 is a box and whisker plot of various sampled volumes for each country using the GENT sampler. The hatched box represents 25% to 75% of the volume distribution, the (+) sign the average and the horizontal bar the median of the distribution. The extended whiskers represent the 95% confidence interval and solid dots are outlier points.

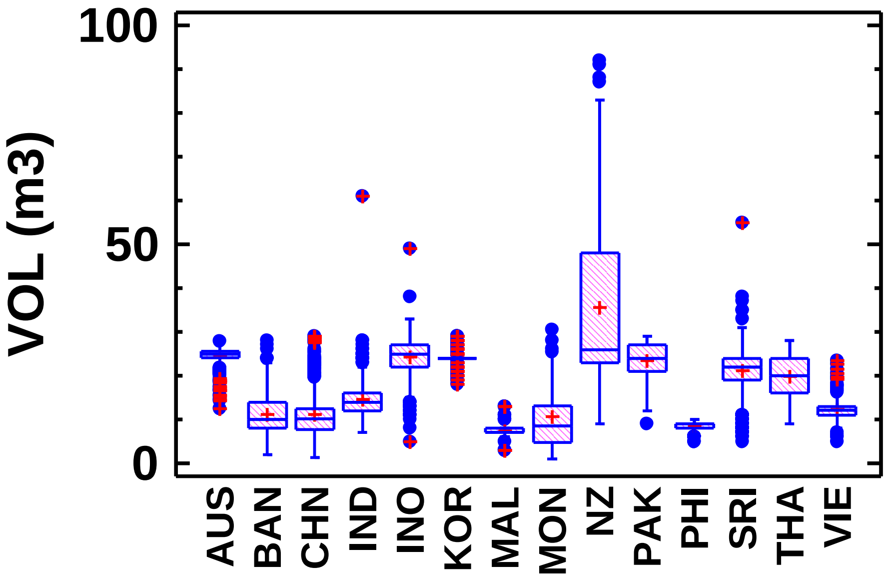

Fig. 3. Box and whisker plot of various sampled volumes for each country using the GENT sampler. (+) is the mean and horizontal bar the median of the volume distribution.

The plot shows that Australia, Indonesia, Korea, Pakistan, Sri Lanka and Thailand tended to generally sample around 20m^3 per filter, whereas other countries used much lower sampling volumes except for New Zealand who actually went the other way and sampled for longer than 24 hours per filter for many filters, producing some average volumes in excess of 30m^3. Outlier points (full dots) below the hatched boxes are produced by low flow rates and heavily loaded days. Outlier points above the hatched boxes are generally due to sampling periods longer the nominal 24 hours where the filters were not changed on time and doubly exposed. It should also be noted that for Korea and the Philippines their hatched boxes were considerably smaller than for most other countries implying significantly less day to day or filter to filter variation in their volumes and hence flow rates during their sampling periods.

Fine Mass Measurements.

Fine mass in the size fraction range below 2.5 µm diameter are mainly produced by combustion processes and therefore have significant health effects. Many countries now have fine particle goals to reflect the health consequences of PM2.5 particles in ambient air.

There are many different possibilities for displaying the data within this dataset and it is not the aim of this report to do this. Here we just present select data to illustrate the content of the current dataset. We can however produce a few graphs which show the potential of such a unique database.

The two box and whisker plots below (Figs. 4 and 5) show the fine and percentage reconstructed mass distributions for each country within the RCA Project. Again the (+) sign within each box represents the mean, the horizontal bar the median and the box contains 25% to 75% of the all points with the whisker showing the 95% confidence interval and the solid dots the outlier points beyond the 95% confidence intervals for each country.

The current US EPA fine particle $PM_{2.5}$ goals are 15 µg/m³ annual average with a maximum of 35 µg/m³ for 24 hours. Different countries have different goals and standards for fine particles. Some have none and some have very tight goals, for example Australia has 8 µg/m³ as an annual average and 25 µg/m³ as a 24 hour maximum. Fig. 4 shows that many countries exceed these goals on many occasions which has significant health implications for large pollutions in urban areas.

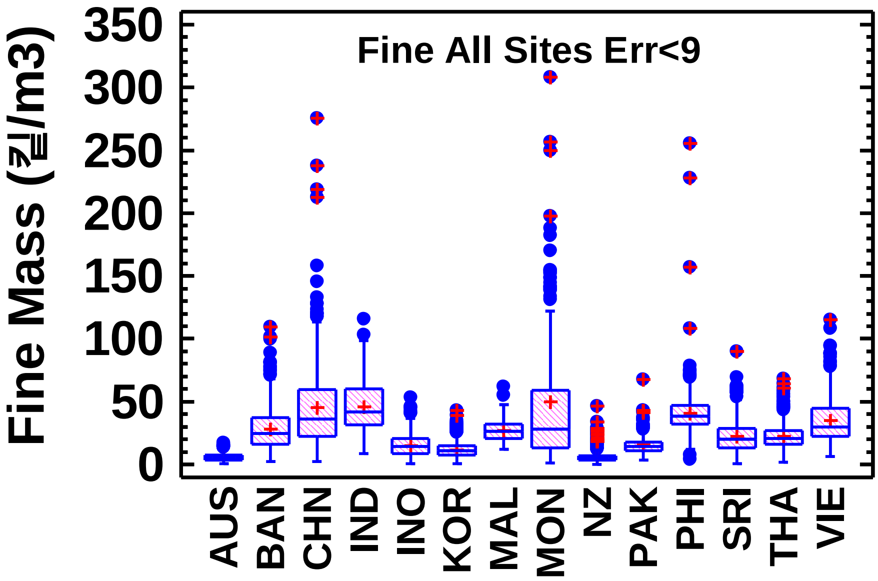

Fig. 4. Box and whisker plot of fine mass concentrations for each country for all data with error code Err<9.

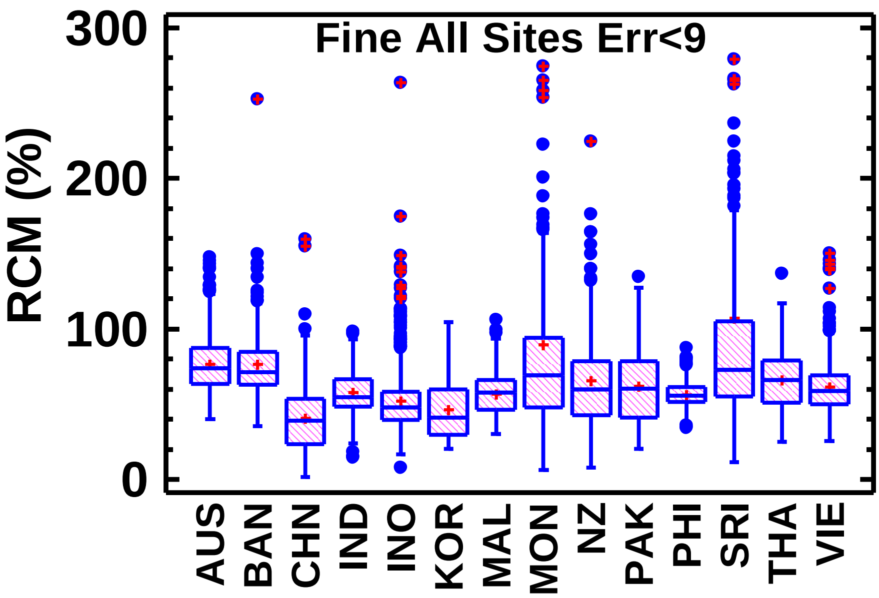

Fig. 5. Box and whisker plot of fine percentage reconstructed mass for each country for all data with error code Err<9.

Fig. 5 shows the reconstructed mass (RCM) as a percentage of the gravimetric mass for all non zero fine mass sampling days. Technically RCM% should be 100% or less but Fig. 5 shows that for most countries values well above this were obtained on some occasions. This occurs because the gravimetric mass is under estimated or the RCM as defined by Equ. (6) is over estimated. Equ. (6) makes many assumptions about the chemical form of many elemental measurements. Some of these may not be true. Generally RCM falls between 40% and 90% for the bulk of the fine data for most countries which is a good mass closure.

Countries using INAA for their elemental analyses (like China and Korea) will generally have a lower RCM as they do no measure Si or S well and these are major components in the calculation of RCM.

Most countries have put an Err=9 in the error column if RCM% exceeds 150%.

Coarse Mass Measurements.

The coarse mass fraction is in the nominal size range 2.5 µm to 10 µm. It is generally dominated by particles generated from mechanical processes such as windblown soils and sea spray. Ideally there should be the same number of fine filters exposed as coarse filters for each site. The data set contains 8,781 fine filters with mass greater than zero and 8,711 coarse filters with mass greater than zero. The small difference being mainly due to weighing problems or errors with some filters.

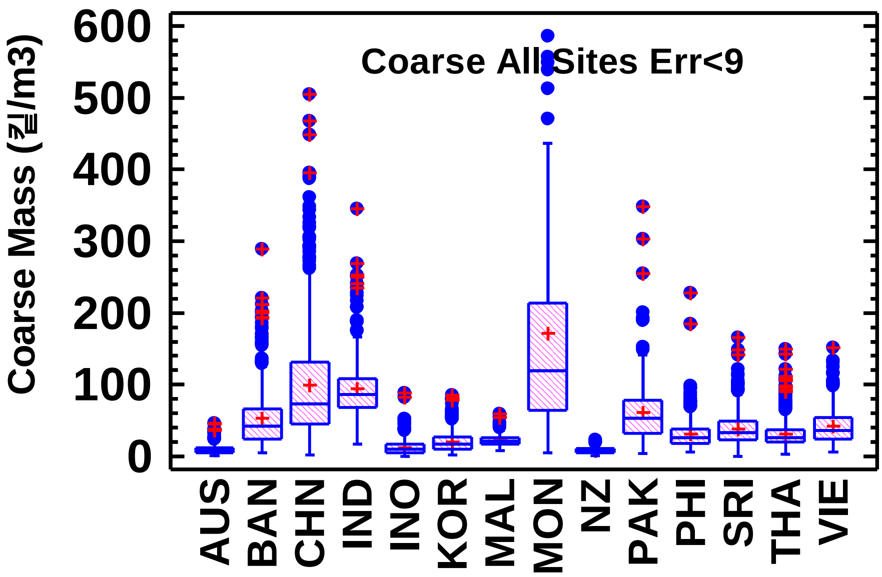

Fig. 6. Coarse mass for each country for all data with error code Err<9.

Fig. 6 is a box and whisker plot for the coarse mass for each country (multiple sites combined) for which the error code Err<9. China, India and Mongolia stand out as having distributions (hatched boxes) that often exceed coarse mass fractions of 100 µg/m³ in a 24 hour period. Pakistan and Bangladesh also have significant coarse fractions above 50 µg/m³ in a 24 hour period. Outlier events above 200 µg/m³ in a 24 hour period were mostly caused by significant dust storms impacting the site.

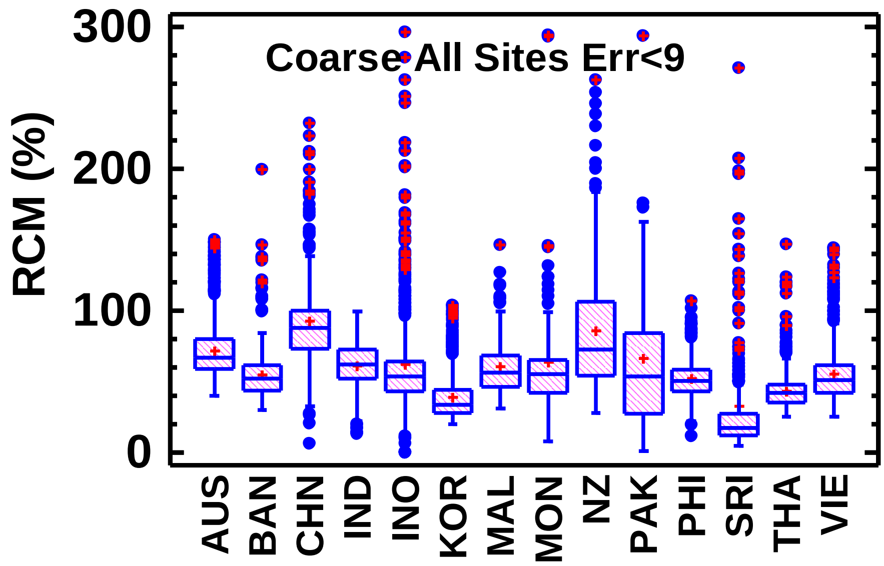

Fig. 7. Box and whisker plot of coarse percentage reconstructed mass for each country for all of their data with error code Err<9.

Fig. 7 is a box and whisker plot of the percentage reconstructed mass as defined by RCM in Equ. (6) as a percentage of the total gravimetric coarse mass. Technically the percentage RCM should be less than 100% and it generally was except for some outlier events where the RCM% exceeded even 200%. This generally occurred because the gravimetric mass had been underestimated when the filters were heavily loaded. Maybe even some of the mass was lost during the weighing process. Alternatively certain major components like black carbon could be grossly over estimated producing high RCM% estimates. For most cases we have put an Err=9 against data with excessively high or excessively low RCM% estimates.

PM10 Measurements.

The GENT unit used by all countries was a stacked filter system with two size fractions, fine and coarse. The addition of the fine, $PM_{2.5}$ fraction, to the coarse (2.5 µm-10 µm) fraction gives an estimate of the PM_{10} mass fraction. Fig. 8 is a box and whisker plot of the PM_{10} size fraction for all countries for all data with error code Err<9. Bangladesh, China, India and Mongolia stand out as the countries with major PM_{10} concentrations.

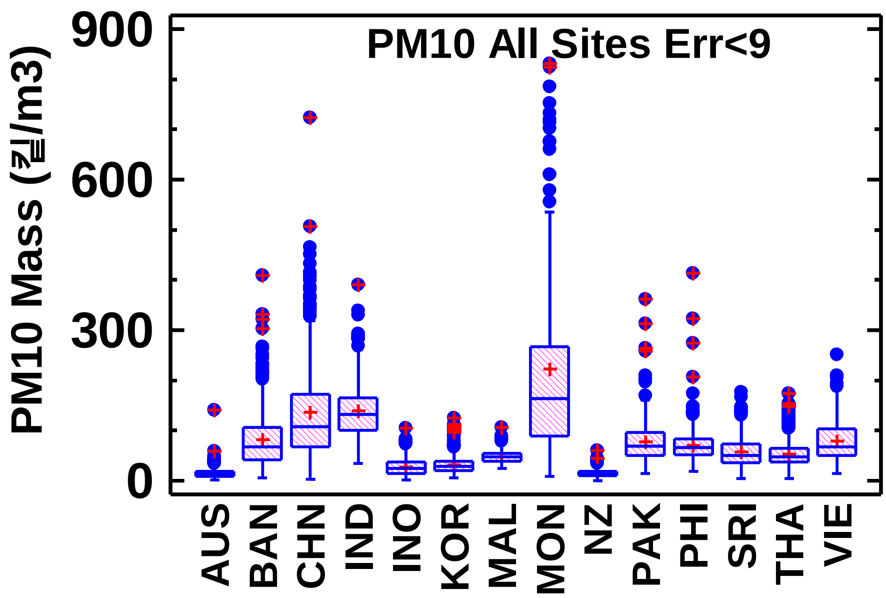

Fig. 8. Box and whisker plot of PM_{10} mass for each country for all data with error code Err<9.

The US NAAQS PM_{10} annual average standard is 50 µg/m^3 with a 24 hour maximum of 150 µg/m^3. Clearly, Fig. 8 shows that several countries exceeded both these goals on a regular basis during the study period.

Fig. 9 is a box and whisker plot for each country of the $PM_{10}/PM_{2.5}$ ratio for all data with error code Err<9. Generally this ratio ranged from 2 to 4 for most countries except Mongolia and Pakistan which ranged from 3 to 6 with outlier events going well above 10. The larger values of the $PM_{10}/PM_{2.5}$ ratio are generally produced by significant dust events impacting these sites and have been used by individual countries to identify long range transport of desert soils for example.

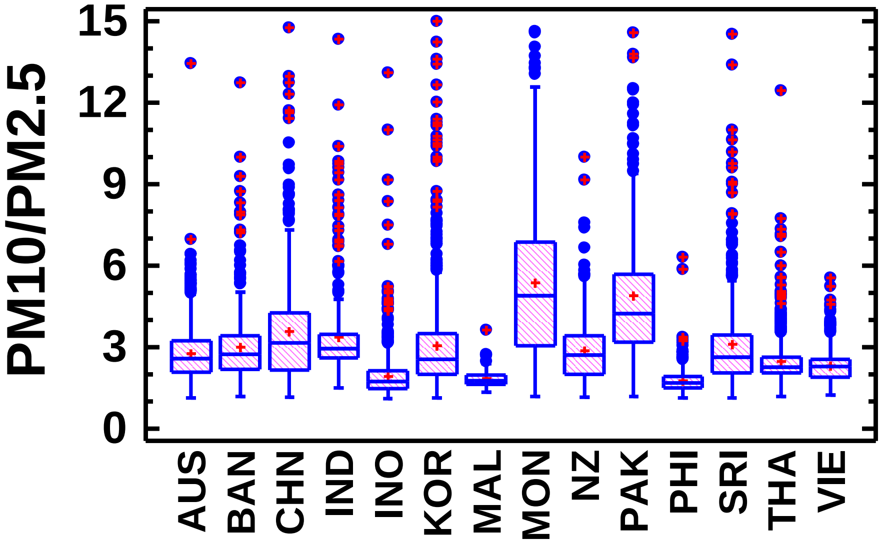

Fig. 9. Box and whisker plot of $PM_{10}/PM_{2.5}$ ratio for each country for all data with error code Err<9.

Fine Soil Measurements.

Soil is a key long range transport component of both fine and coarse particles. As mentioned above we estimate the soil component from Equ. (3) using the five key elements Al, Si, Ca, Ti and Fe in their common oxide forms.

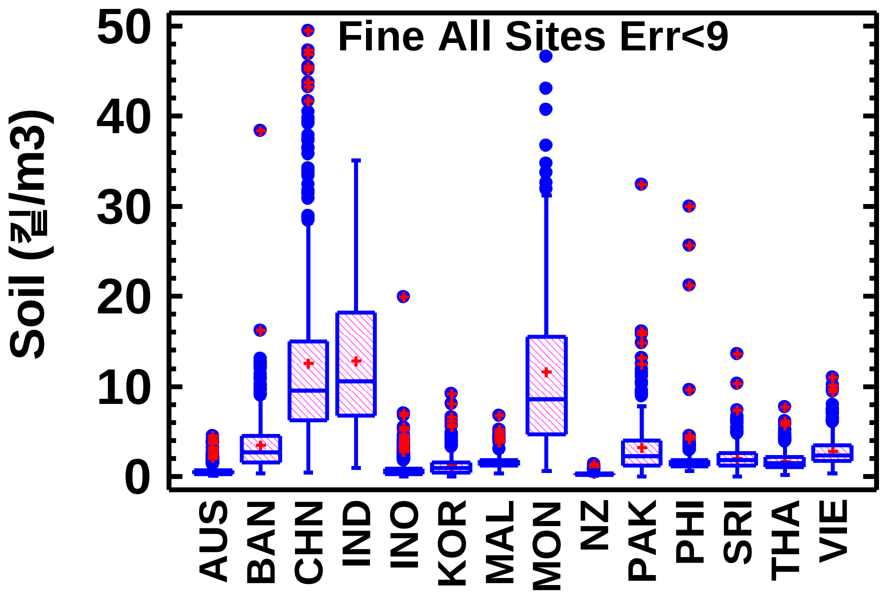

Fig. 10. Box and whisker plot of fine soil for each country for all data with error code Err<9.

Fig. 10 is a box and whisker plot for fine soil for each country (multiple sites combined) for which the error code Err<9. Clearly China, India and Mongolia are sites significantly impacted by fine soils.

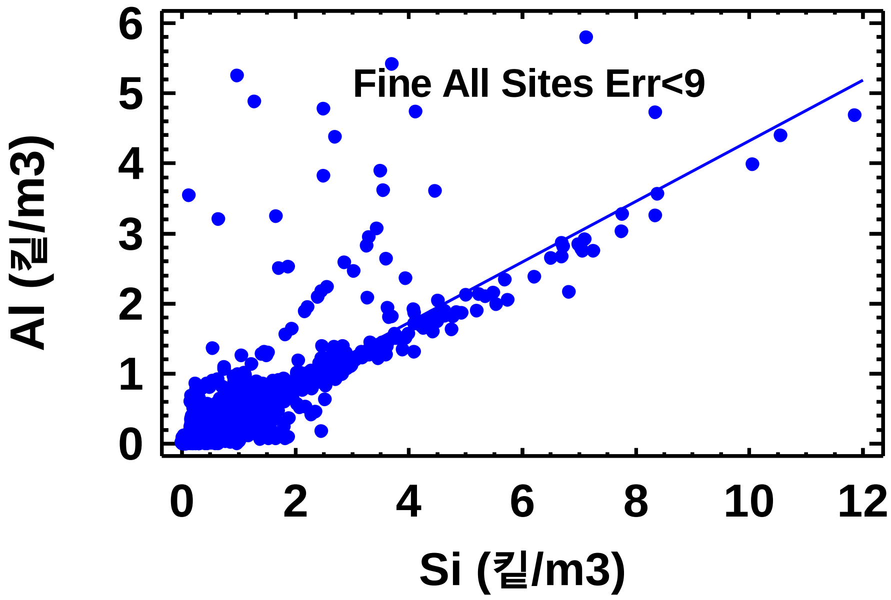

Fig. 11. A fine Al vs Si correlation plot for all countries and for all data with error code Err<9.

Aluminium and silicon are key indicators of soil. This is well demonstrated by the good correlation shown in the plot of Fig. 11. A linear fit of Al versus Si for all sites and all countries with Al and Si greater than zero and filters with Err<9 gives,

$$\text{Al (Fine)} = (0.396 \pm 0.23) * \text{Si (Fine) and } R^2 = 0.77 \qquad (11)$$

The points above the line with high Al not associated with Si were probably due to Al sources other than soil, like Al smelters for example. This is a very good correlation considering that the data contains 23 different sampling sites across 14 different countries.

Equ. (11) can be used to estimate Si from Al if, as with INAA analyses, you can not make a meaningful Si measurement. This is a good technique for China and Korea who do not have any fine Si numbers to estimate their Si content from their Al measurements using Equ. (11).

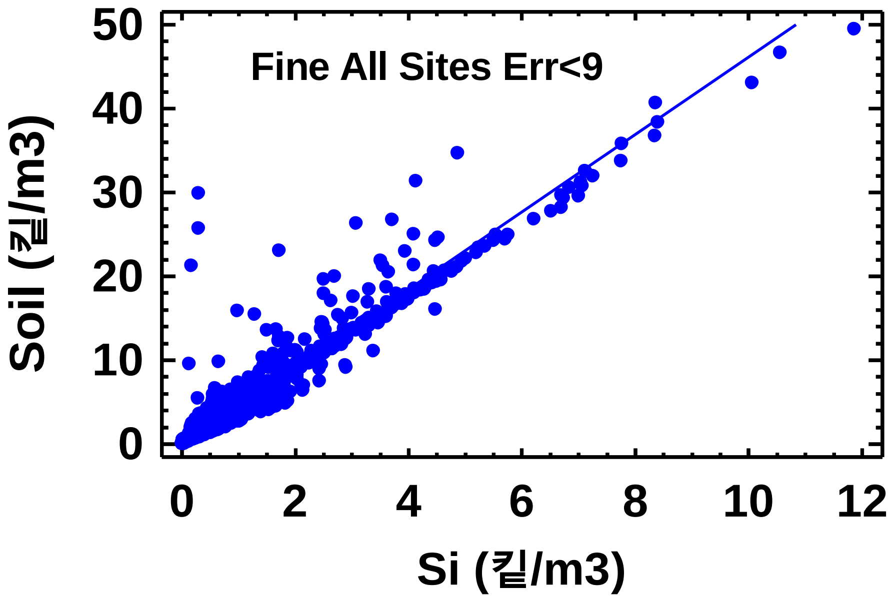

Fig. 12. A fine Soil vs Si correlation plot for all countries and for all data with error code Err<9.

Since the Al vs Si plot showed such good correlations across all countries it is instructive to plot the Soil vs Si correlations for countries that have measured Si. Such a plot is shown in Fig. 12 for all data with Err<9.

There are over 6,600 points in this plot. Again a linear fit of Soil versus Si for all sites with Soil and Si greater than zero and filters with Err<9 gives,

$$\text{Soil (Fine)} = (4.35 \pm 1.1) * \text{Si (Fine) and } R^2 = 0.95 \quad (12)$$

The correlation coefficient R^2=0.95 is excellent. A similar plot for Soil versus Al gives,

$$\text{Soil (Fine)} = (10.6 \pm 4.1) * \text{Al (Fine) and } R^2 = 0.75 \quad (13)$$

Again with a reasonably good correlation coefficient of R^2=0.75.

Again Equs. (12) and (13) can be used to estimate fine soil from either a Si or an Al concentration measurement.

Coarse Soil Measurements.

Generally one would expect the soil component in the coarse fraction to be higher than that found in the fine fraction. A comparison of Fig. 13 with Fig. 10 shows this to be the case for each of the 14 countries particularly for countries with high soil components from dust storms like China, Mongolia and Pakistan.

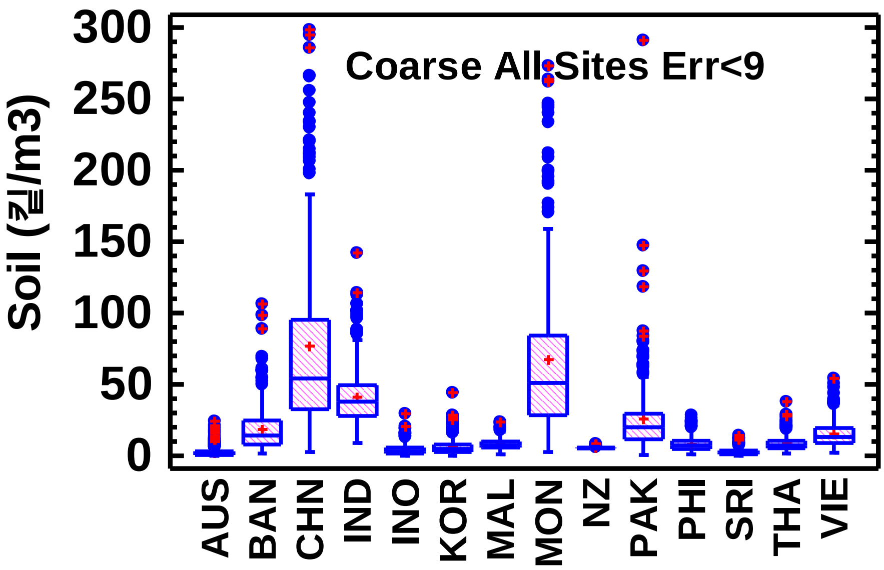

Fig. 13. Box and whisker plot of coarse soil for each country for all data with error code Err<9.

China, India and Mongolia stand out as having higher coarse soil fractions than other countries. These countries are impacted by long range transport of soil from known desert regions [3, 12, 13, 42]

A linear fit of Al versus Si for all sites with Al and Si greater than zero and filters with Err<9 gives,

$$\text{Al (Coarse)} = (0.343 \pm 0.11) * \text{Si (Coarse) and } R^2 = 0.93 \quad (14)$$

Fig. 14 is a plot of the coarse Al versus the coarse Si for all sites and all countries and is similar to Fig. 11 as demonstrated by the similar correlation Equs. (11) and (14). Fine soil does contain slightly more Al than coarse soil, but when the errors are taken into account this is hardly significant. Typically the [Al/Si] ratio is between 0.34 and 4.0 for silicon concentrations up to 12 µg/m³ which corresponds to soil estimates up to 50 µg/m³.

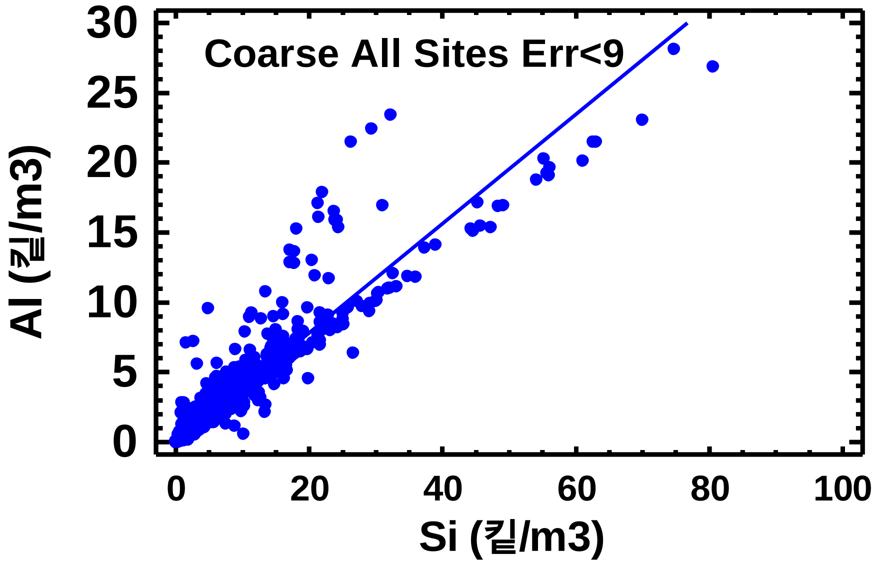

Fig. 14. A coarse Al vs Si correlation plot for all countries and for all data with error code Err<9.

The points above the line of best fit in Fig. 14 represent Al not associated with Si in soils and probably arise from Al from other anthropogenic sources or industrial sources such as aluminium smelting for example.

Fig. 15 is a plot of the coarse soil against the silicon concentration, the correlation is excellent with R^2=0.98 from more than 5,600 points covering all sites in all countries.

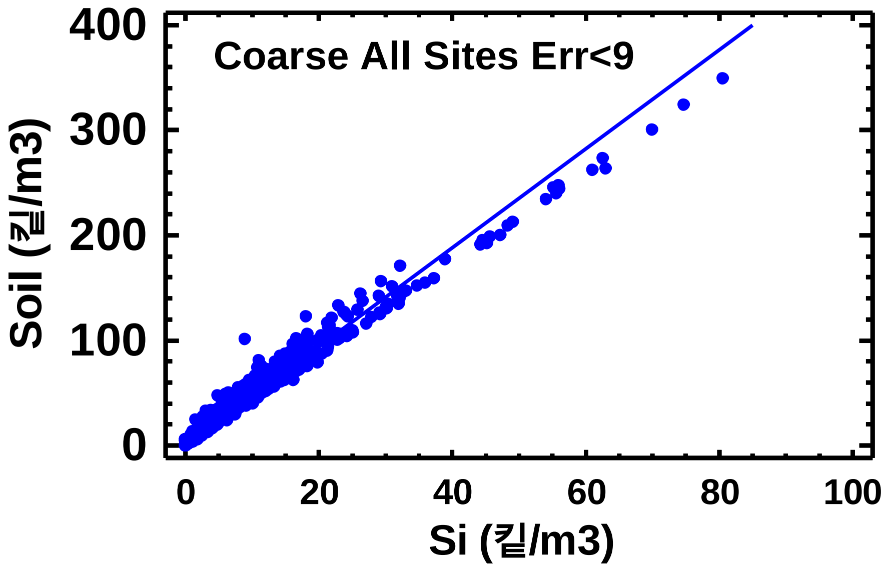

Fig. 15. A coarse Soil vs Si correlation plot for all countries and for all data with error code Err<9.

Again a linear fit of coarse Soil versus coarse Si for all sites with Soil and Si greater than zero and filters with Err<9 gives,

$$\text{Soil (Coarse)} = (4.360 \pm 0.63) *\text{Si (Coarse) and } R^2 = 0.98 \quad (15)$$

Similar plots for coarse Soil versus coarse Al give,

$$\text{Soil (Coarse)} = (12.27 \pm 2.7) *\text{Al (Coarse) and } R^2 = 0.95 \quad (16)$$

The Si and Al content of soil was fairly consistent across both fine and coarse fractions as demonstrated in Equs. (11) and (13) and (14) and (16) respectively.

For techniques like INAA that do not measure Si well but do a reasonable job on Al, estimates of Si and Soil can be still be obtained from the Al measurements via the above equations and fits for both fine and coarse size fractions.

Fine Black Carbon Measurements.

Black carbon (BC) or soot is a key component of the fine fraction of particulate matter. It originates from combustion process such as biomass burning and emissions from motor vehicles. Typically BC particle sizes are much less than 1 μm in diameter. Fine black carbon was measured by all countries using the standard reflectometer systems provided by the IAEA. Fig. 16 is a box and whisker plot of fine BC for each of the14 countries in the project.

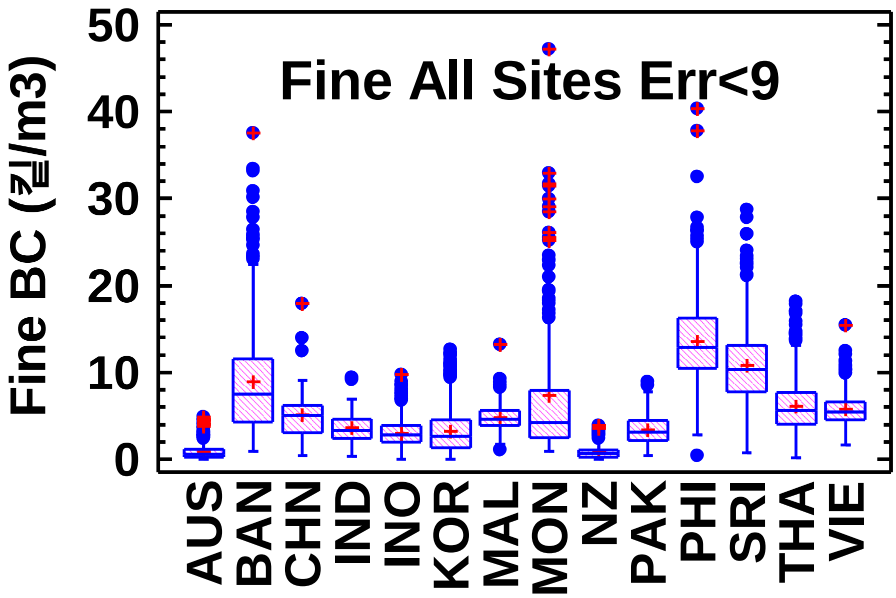

Fig. 16. Box and whisker plot of fine black carbon (BC) for each country for all data with error code Err<9.

In order to estimate the fine BC component from these measurements one must assume a constant mass absorption coefficient ε in m^2/g. Typically values of ε for submicron aerosols range from 5-10 m^2/g [8]. The values used by each country in the RCA program can be found in column 7 of Table A1 in Appendix 1.

The Philippines had the highest average BC measurements, with Bangladesh, Mongolia, Sri Lanka, Thailand and Vietnam not far behind.

Many countries measured BC for the coarse filters as well and used the same mass attenuation coefficient as for their fine particle BC estimates. This is generally not correct as BC mass absorption coefficients for coarse particles can be an order of magnitude lower than for fine particles and depends critically on the particle size. Hence coarse BC measurements in this dataset (where they exist) should be used with great caution as they are most probably not very meaningful. A fuller discussion on values of ε with particle size and type can be found in the work of reference [8].

Fine Sulfur Measurements.

Sulfur in the form of sulfate is another major component of fine particulate ambient aerosols. It too generally has particle sizes below 1 μm in diameter. The fully neutralised form of ammonium sulfate can be estimated from the sulfur concentrations via Equ. (2). It is an important component to measured as it can occur in many different fine particle sources from coal fired power station emissions to sea spray.

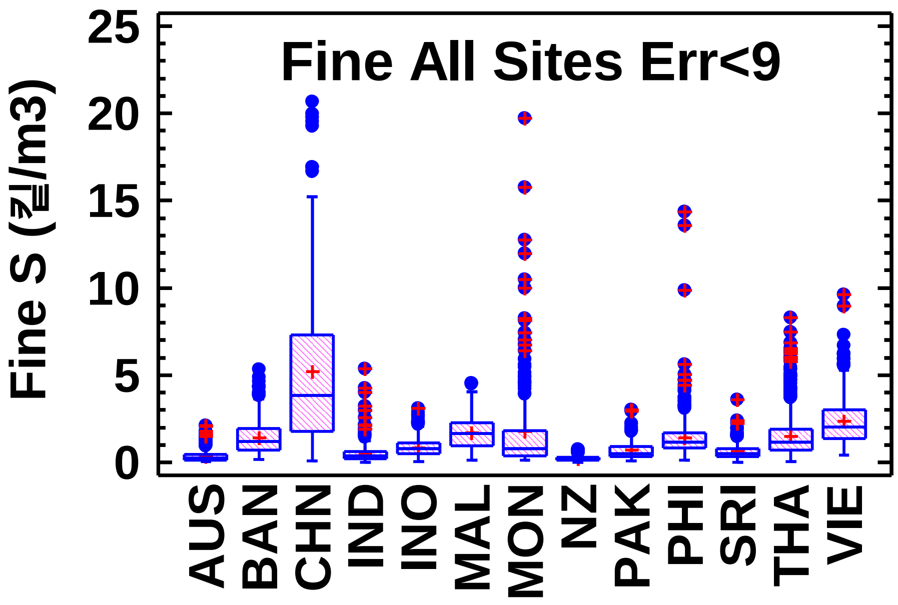

Fig. 17. Box and whisker plot of fine sulfur for each country for all data with error code Err<9.

Fig. 17 is a box and whisker plot of the fine sulfur for each country for all data with error codes Err<9. Note there is no data for Korea as they used INAA techniques to determine elemental concentrations and sulfur was not included.

Summary

Table 1 below summarises in numerical form many of the figures produced above for fine and coarse size fractions. It includes the number of filters for each country (all sites) with gravimetric mass measurements above zero and with error code Err<9. All measurements are in (ng/m^3) the same as in the dataset itself. Data for the key components of soil, black carbon and ammonium sulfate are provided.

	All Sites Fine Mass> 0 Err<9				All Sites Coarse Mass> 0 Err<9			
Australia	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	1,130	1,130	1,130	1,130	1,074	1,074	1,074	1,074
Average	5,560	573	807	1,369	9,015	2,310	101	527
Median	5,093	409	547	1,068	8,056	1,511	106	432
SD	2,987	507	771	1,073	5,632	2,493	150	377
Maximum	17,110	4,508	4,872	8,723	46,490	24,368	1,500	2,183
Bangladesh	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	423	423	423	423	403	403		403
Average	28,287	3,506	8,889	5,869	52,845	18,625		4,769
Median	24,716	2,698	7,530	4,922	41,655	14,068		3,619
SD	16,811	3,044	6,050	3,868	42,124	14,786		4,057
Maximum	109,290	38,349	37,530	22,030	289,099	106,435		24,059
China	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	455	455	56	235	420	420		55
Average	45,069	12,596	5,082	21,523	99,829	76,676		14,024
Median	36,044	9,548	5,015	15,789	73,306	54,269		9,744
SD	33,247	11,284	3,164	19,498	89,549	65,852		13,790
Maximum	275,758	115,279	17,921	143,460	876,498	417,321		86,108
India	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	355	355	354	355	355	355	237	355
Average	44,907	12,864	7,951	2,469	93,869	41,157	6,537	6,783
Median	41,860	10,563	6,858	1,868	86,560	37,745	6,700	5,910
SD	18,878	8,078	4,626	2,625	42,332	20,044	2,265	4,174

Maximum	115,830	35,089	25,740	22,156	345,455	142,213	13,460	33,512
Indonesia	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	932	931	932	771	977	977	971	823
Average	14,952	766	2,991	3,437	12,183	3,889	715	1,236
Median	14,240	523	2,833	3,303	10,233	3,156	618	1,044
SD	8,177	990	1,491	2,008	9,494	3,197	541	1,027
Maximum	53,125	19,966	9,750	12,821	88,000	29,304	5,214	13,614
Korea	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	885	885	885		739	739		
Average	11,560	1,195	3,252		20,263	6,216		
Median	10,710	989	2,665		17,490	4,802		
SD	5,958	989	2,470		13,251	5,062		
Maximum	42,840	9,177	12,593		85,417	44,452		
Malaysia	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	168	168	168	168	145	145	145	145
Average	26,702	1,692	4,760	7,007	21,752	8,450	554	1,941
Median	26,180	1,503	4,592	6,746	20,710	7,627	466	1,720
SD	8,324	868	1,556	3,989	7,750	3,979	541	1,109
Maximum	62,110	6,723	13,201	18,657	59,170	23,913	5,399	10,106
Mongolia	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	295	295	295	295	296	296	296	296
Average	49,794	11,624	7,359	7,386	172,006	67,248	4,850	5,950
Median	28,219	8,616	4,249	3,245	119,143	51,110	3,776	3,737
SD	84,234	12,018	10,019	15,099	177,867	57,475	4,196	7,400
Maximum	1,209,820	152,387	103,049	165,328	1,253,190	349,215	38,581	75,376
New Zealand	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	433	433	433	433	330	330	330	330
Average	6,134	313	1,224	876	8,271	5,626	671	857
Median	5,000	249	761	760	7,633	5,472	324	694
SD	4,850	204	1,519	550.606	3,906	491	749	533
Maximum	46,190	1,408	10,713	3,016	23,333	8,604	3,491	3,680
Paskistan	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	229	229	229	157	255	255	255	176
Average	15,710	3,231	3,388	2,838	60,950	25,809	1,802	2,761
Median	14,231	2,240	3,127	2,032	52,857	19,784	1,723	2,090
SD	8,051	3,457	1,629	2,210	45,343	27,069	935	2,323
Maximum	67,826	32,441	8,925	12,351	348,148	290,952	5,289	16,308
Philippines	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	631	631	631	631	620	620	620	620
Average	40,503	1,676	13,561	5,852	30,786	8,090	2,094	1,809
Median	38,243	1,389	12,862	4,835	26,207	7,215	1,939	1,400
SD	17,246	1,809	4,731	5,016	19,029	4,772	962	1,753
Maximum	255,498	29,952	40,346	59,297	227,541	28,489	10,527	31,880
Sri Lanka	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	443	443	443	443	358	358	358	49
Average	22,234	2,001	10,794	2,462	38,492	2,676	3,497	7,981
Median	20,000	1,825	10,340	2,067	33,270	1,926	3,300	7,442
SD	12,594	1,475	4,148	1,615	24,131	2,342	455	3,195
Maximum	90,000	13,573	28,710	14,783	166,000	13,999	8,100	17,597
Thailand	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	929	929	929	843	929	929	929	328
Average	22,219	1,681	6,085	6,049	30,795	8,453	1,407	3,023
Median	20,692	1,454	5,582	4,736	25,826	7,316	1,223	2,023
SD	9,321	934	2,775	4,754	18,017	4,722	846	3,443

Maximum	68,182	7,740	18,144	34,200	149,563	37,918	6,416	29,894
Vietnam	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**	**Mass**	**Soil**	**BC**	**$(NH_4)_2SO_4$**
No Samples	428	428	428	428	352	352		352
Average	34,748	2,772	5,735	9,678	42,247	15,080		3,994
Median	29,591	2,361	5,422	8,260	35,979	13,087		2,739
SD	17,075	1,563	1,854	5,670	24,570	8,744		3,728
Maximum	115,000	11,005	15,414	39,699	151,843	54,103		23,462

Table 1. The average, median, standard deviation and maximum concentrations of fine and coarse mass, soil, black carbon and ammonium sulfate for each country.

For completeness we quote up to 6 significant figures for the (ng/m^3) concentrations in Table 1. But when the errors and associated MDL's are considered it would be more appropriate to use only 2 or at most 3 significant figures for most of the concentrations quoted in this table. But for consistency we prefer to quote this Table in (ng/m^3) and not convert it to (µg/m^3).

This dataset is now in its final form. The format has been standardised across all countries and 14 countries have contributed fine and coarse concentrations with errors and MDLs. We believe this current database meets most of the criteria of a "good database" as listed in an earlier section of this document.

In summary,

- Database is in a reasonably good shape as of 30 November 2010, All of 14 countries have contributed data between May 2000 and December 2009
- The sampling overlap of data between countries essentially spans the 5 year time period from January 2003 to December 2007 inclusive.
- Most countries have provided data for Concs, Errors and MDLs worksheets for fine and coarse filters. There are over 8,800 daily entries for fine and coarse filters.
- Most countries have analysed these filters for at least 15 different elemental species and in some cases 40 species have been determined.
- Error codes have been inserted on known problem days. The current dataset has about 12% fine and 18% coarse data with Err=9.
- Other quality checks have been performed on the full dataset, including sample volume checks and reconstructed mass being within reasonable limits for the analyses performed. Where known problems have occurred an error code Err=9 has been inserted against that sampling day.
- Each country has compiled a list of known problems associated with their data and these are listed in the "Problems" worksheet associated with the dataset.
- Macros were written to scan the data for each country to check basic consistencies like one to one correspondence between dates in fine, coarse, errors and MDL data files. Hopefully all these types of errors have been eliminated.

This is a unique database. We are not aware of any other dataset of fine and coarse particulate matter measurements with nuclear multi-elemental analyses spanning more than 5 years and 14 countries in Asia. This dataset has the potential to be used to determine source fingerprints and source contributions to fine and coarse particulate pollution. Indeed this has already been achieved by several countries. This dataset should be useful to pollution managers and to researchers alike and we believe will be a valuable resource for many years to come.

Acknowledgements

I would like to acknowledge the initial extensive work of Professor Philip Hopke in establishing the first dataset for all countries in this RCA Project and to all countries for providing their data. Professor Willy Maenhaut for providing the GENT stacked filter units and for training during the course of this project. Also the extensive help of Dr Rainer Siegele in combining each country's data into one large dataset. This work has been performed under contract from the IAEA.

References

The following is a list (alphabetically by country) of refereed journal publications related to the database and provided by each country. It contains 95 journal publications produced during the course of this work.

Australia

[1] P.K. Hopke, S. Biegalski, S. Landsberger, W. Maenhaut, P. Artaxo, D. Cohen. Characterisation of the GENT PM10 Sampler. Aerosol Science and Technology 27 (1997) 726-735.

[2] David D.Cohen Ed Stelcer, David Garton. Ion beam methods to determine trace heavy metals concentrations and sources in urban airsheds. Nuclear Instruments and Methods in Physics Research B190 (2002) 466-470

[3] David D. Cohen, David Garton, Eduard Stelcer, Olga Hawas, Tao Wang, Steven Poon, Jiyoung Kim, Byoung Cheol Choi, Sung Nam Oh, Hye-Jung Shin, Mi Young Ko,Mitsuo Uematsu, Multi-elemental Analysis and Characterisation of Fine Aerosols at Several Key ACE-Asia Sites. Journal of Geophysical Research, 109 (2004) D19S12, doi:10.1029/2003JD003569.

[4] David D. Cohen, Ed Stelcer, Olga Hawas, David Garton, IBA Methods for Characterisation of Fine Particulate Atmospheric Pollution: A local, regional and global research problem. Nucl. Instr. and Methods B219-220 (2004) 145-152.

[5] David D. Cohen, David Garton, Eduard Stelcer, Olga Hawas, Accelerator Based Studies of Atmospheric Pollution Processes. Radiation Physics and Chemistry, 71 (2004) 759-767.

[6] D. D. Cohen, B. L. Gulson, J. M. Davis, E. Stelcer, D. Garton, O. Hawas, Fine-particle Mn and other metals linked to the introduction of MMT into gasoline in Sydney, Australia: Results of a natural experiment. Atmospheric Environment, 39 (2005) 6885-6896.

[7] Ed Stelcer, Olga Hawas, David Cohen, Adam Sarbutt, David Button, Will air quality in Australia meet proposed fine particle NEPM guidelines? Int. J. PIXE, 15 (2005) 233-239.

[8] G. Taha, G. P. Box, D. D. Cohen, E. Stelcer. Black Carbon Measurement using Laser Integrated Plate Method. Aerosol Science and Technology, 41 (2007) 266-276.

[9] Y. Chan, David D. Cohen, Olga Hawas, Eduard Stelcer, Rod Simpson, Lyn Denison, Neil Wong, M. Hodge, E. Comino, S. Carswell. Apportionment of sources of fine and coarse particles in four major Australian cities by positive matrix factorisation. Atmos. Environ., 42 (2008) 374-389.

[10] Philip Hopke, David D. Cohen, Bilkis A. Begum, Swapan K. Biswas, Bangfa Ni, Gauri Girish Pandit, Muhayatun Santoso, Yong-Sam Chung, Perry Davy, Andreas Markwitz, Shahida Waheed, Naila Siddique, Flora L. Santos, Preciosa Corazon B. Pabroa, Manikkuwadura Consy Shirani Seneviratne, Wanna Wimolwattanapun, Supamatthree Bunprapob, Thu Bac Vuong, Andrzej Markowicz. Urban air quality in the Asian region. Science of the Total Environment 404 (2008) 103-112.

[11] David D Cohen, Ed Stelcer, Flora L. Santos, Michael Prior, Craig Thompson, Preciosa C. B. Pabroa. Fingerprinting and source apportionment of fine particle pollution in Manila by IBA and PMF techniques; A 7 year study. X-ray Spectrometry 38 (2009) 18-25.

[12] David D. Cohen, Jagoda Crawford, Eduard Stelcer, Vuong Thu Bac, Characterisation and source apportionment of fine particulate sources at Hanoi from 2001 to 2008. Atmos. Environ., 44 (2010) 320-328.

[13] David D. Cohen Jagoda Crawford, Eduard Stelcer, Vuong Thu Bac. Long Range Transport of Fine Particle Windblown Soils and Coal Fired Power Station Emissions into Hanoi between 2001 to 2008. Atmos. Environ., 44 (2010) 3761-3769.

Bangladesh

[14] Swapan K. Biswas, Solaiman A. Tarafdar, Ashraful Islam, M. Khaliquzzaman, Heikki Tervahattu and Kaarle Kupiainen, Impact of unleaded gasoline introduction on the concentration of lead in the air of Dhaka, Bangladesh, 2003, J. Air and Waste Management Association, 53, 1355-1362.

[15] Bilkis A. Begum, Eugene Kim, Swapan K. Biswas, and Philip K. Hopke, Investigation of sources of atmospheric aerosol urban and semi-urban areas in Bangladesh by positive matrix factorization, Atmospheric Environment, 38, 2004, 3025-3038.

[16] Bilkis A. Begum and Swapan K. Biswas, Characteristics of PM2.2 and PM2.2-10 in the Atmosphere of Dhaka City, Nuclear Science and Applications, 13, 2004, 9-19.

[17] Bilkis A. Begum, Swapan K. Biswas, Eugene Kim, Philip K. Hopke and M.Khaliquzzaman, Investigation of sources of atmospheric aerosol at a hot spot area in Dhaka, Bangladesh. J. Air and Waste Management Association, 55, 2005, 227-240.

[18] Bilkis A. Begum, Eugene Kim, Cheol-Heon Jeong, Doh-Won Lee, and Philip K. Hopke, Evaluation of the potential source contribution function using the 2002 Quebec forest fire episode. Atmospheric Environment, 39, 2005, 3719-3724.

[19] Pentti Paatero, Philip K. Hopke, Bilkis A. Begum, Swapan K. Biswas, A graphical diagnostic method for assessing the rotation in factor analytical models of atmospheric pollution. Atmospheric Environment, 39, 2005, 193-201.

[20] Bilkis A. Begum, Hopke, P.K., Weixiang Zhao, Source identification of fine particles at Washington DC by ME-2 modeling. Environmental Science and Technology, 39, 2005, 1129-1137.

[21] Bilkis A. Begum and Swapan K. Biswas, Comparison of PM collection efficiency of Gent and Airmatrics MiniVol Portable Air Sampler. Nuclear Science and Applications, 14, 2005, 79-83.

[22] Bilkis A. Begum, Biswas, S.K., Hopke, P.K., Temporal variations and spatial distribution of ambient PM2.2 and PM10 concentrations in Dhaka, Bangladesh″. The Science of the Total Environment, 358, 2005, 36-45.

[23] Bilkis A. Begum, Swapan K. Biswas, Hopke, P.K., Impact of Banning of Two-stroke Engines on Air Quality in Dhaka, Bangladesh. J. Air and Waste Management Association, 56, 2006, 85-89.

[24] Bilkis A. Begum, and Swapan K. Biswas, Ambient concentration of PM2.2 and PM10 in Rajshahi City and comparison with Dhaka City of Bangladesh. Nuclear Science and Applications, 15, 2006, 14-22.

[25] Bilkis A. Begum, Yeasmin N. Jolly, Swapan K. Biswas, Elemental analysis of air particulate matter and application to source fingerprinting. J. Bangladesh Academy of Sciences, 30, 2006, 85-93.

[26] Bilkis A. Begum, Swapan K. Biswas, Philip K. Hopke and David D. Cohen, Multi-element analysis and Characterization of Atmospheric particulate pollution in Dhaka. Aerosol and Air Quality Research, 6, 2006, 334-359.

[27] B. A. Begum, S.K. Biswas, P. K. Hopke, D.D. Cohen, Multi-elemental analysis and characterisation of atmospheric particulate pollution in Dhaka. Aerosol and Air Quality Research, 6 (2006) 334-359.

[28] Bilkis A. Begum, Shirin Akhter, Lipi Sarker and Swapan K. Biswas, Gravimetric Analysis of air filters and quality assurance in weighing. Nuclear Science and Applications, 15, 2006, 36-41.

[29] Bilkis A. Begum, Swapan K. Biswas, and Philip K. Hopke, Source apportionment of air particulate matter by Chemical Mass Balance (CMB) and Comparison with Positive Matrix Factorization (PMF) Model. Aerosol and Air Quality Research, 7, 2007, 446-468.

[30] Bilkis A. Begum, Swapan K. Biswas and M. Khaliquzzaman, Characteristics of particulate pollutants in Dhaka and impact of policy interventions. J. Bangladesh Chemical Society, 20, 2007, 86-98.

[31] Bilkis A. Begum, and Swapan K. Biswas, Characteristics of particulate matter at two Traffic Hot Spot areas in Dhaka City. Nuclear Science and Applications, 16, 2007, 45-54.

[32] Bilkis A. Begum, Swapan K. Biswas, Mohammed A. Matin and Mohammed M. Hoque and Philip K. Hopke, Trace elements analysis of archeological brick samples collected from different historical places in Rajshahi Division. Nuclear Science and Applications, 16, 2007, 11-21.

[33] Bilkis A. Begum and Swapan K. Biswas, Trend in particulate matter (PM) and lead pollution in ambient air of Dhaka city in Bangladesh. J of Bangladesh Academy of Science, 32, 2008, 155-164.

[34] Bilkis A. Begum, Swapan K Biswas, and Philip K Hopke, Assessment of trends and present ambient concentrations of PM2.2 and PM10 in Dhaka, Bangladesh. Air Qualily and Atmospheric Health, 2008, DOI 10.1007/s118, 69-008-0018-7.

[35] Bilkis A. Begum and Swapan K. Biswas, Characterization and apportionment of sources of indoor air particulate matter of AECD campus, Dhaka. J of Bangladesh Academy of Science, 33 (1), 2009, 25-36.
Bilkis A. Begum, A. Tazmin, K.A. Rabbani, Swapan K. Biswas, and M. Nasiruddin, Investigation of sources of particulate matter from the Tajgaon Industrial area, Dhaka. J of Bangladesh Academy of Science, 33 (1), 2009, 71-85.

[36] Bilkis A. Begum, Samir K. Paul, M. D. Hossain, Swapan K. Biswas and Philip K. Hopke, Indoor air pollution from particulate matter emissions in different households in rural areas of Bangladesh. Building and Environ.44, 2009, 898-903.

[37] Bilkis A. Begum,Swapan K. Biswas, Mohammed Nasiruddin, Abul Monsur Showkot Hossain and Philip K. Hopke, Source Identification of Chittagong Aerosol by Receptor Modeling. Environmental Engineering Science, 26, 2009, 679-689.

[38] Bilkis A. Begum, Naima A. Khan, M. Khabir Uddin and Swapan K. Biswas, Characteristics and short-range transport of particulate matter from Dhaka-Aricha highway. J. Bangladesh Chemical Society, 22(1), 2009, 18-34.

[39] Bilkis A Begum, M. Nasiruddin and Swapan K Biswas, Trend and spatial distribution of air particulate matter pollution in Dhaka city. J. Bangladesh Academy of Sciences, 34, 151-157, 2010.

[40] Bilkis A. Begum, Swapan K. Biswas, Andreas Markwitz and Philip K Hopke, Identification of sources of fine and coarse particulate matter in Dhaka Bangladesh. Aerosol and Air Quality Research, 10, 345-353, 2010.

[41] Bilkis A. Begum, Swapan K. Biswas and Philip K Hopke, Key issues for control air pollutants in Dhaka, Bangladesh. Atmospheric Environment, 2010, Accepted.

[42] Bilkis A. Begum, Swapan K. Biswas, Gauri G. Pandit, Shahida Waheed, Manikkuwadura Consy Shirani Seneviratne, David D. Cohen, and Andreas Markwitz Philip K Hopke, Long-range transport of soil dust and smoke pollution in the South Asian Region. Atmospheric Pollution Research, 2010, in press.

China

[43] Ni Bangfa, Tian Weizhi, Wang Pingsheng, Zhang Lanzhi, Zhang Guiying, Liu Cunxiong, Huang Donghui, Li Dehong, Study on air pollution in Beijing's major industrial areas using multielements in biomonitors and NAA techniques; International Journal of Environment and Pollution Vol. 32(4) (2008) 456 - 466.

[44] Huang Donghui, Xiao Caijin, Ni Bangfa, Tian Weizhi, et al., Characterization of a Stream Sediment Matrix Material for Sampling Behavior in order to Use it as a CRM, Applied Radiation and Isotopes, Vol.68 (2010) 37-41.

[45] M.Ebihara, Y.S. Chuag, W.chueinta, B-F. Ni , T. Otoshi , et al, Collaboration Monitoring Study of Airborne Particulate matters among seven Asian countries, J. of Radioanl. Nucl. Chem. Vol. 269(2) (2006) 259-266.

[46] Huang Donghui , Wang Pingsheng , Ni Bangfa , Half-life of ^{97}Zr re-measured , J. of Radioanl. Nucl. Chem. Vol. 265(3) (2005) 499-503.

[47] Tian Weizhi, Nuclear analytical methods in quality control of microanalysis, Journal of Radioanalytical and nuclear chemistry, Vol.262(1) (2004) 223-228.

[48] Lei Cao, Weizhi Tian, Bangfa Ni, Pingsheng Wang,Yangmei Zhang, Radiochemical neutron-activation analysis of uncertified ultra-trace rear earth elements in two biological certified reference materials, Anal. Bioanal. Chem. 372 (2002) 397-400.

[49] Lei Cao, Weizhi Tian, Bangfa Ni, Yangmei Zhang, Pingsheng Wang, Preliminary study of airborne particulate matter in a Beijing sampling station by instrumental neutron activation analysis, Atmospheric Environment, 36 (2002) 1951-1956.

[50] Weizhi Tian, Bangfa Ni, Yangmei Zhang, Lei Cao, Metrological of Neutron Activation Analysis. III. Role of INAA in sampling behaviour characterization, Accred Qual Assur., Vol. 7 (2002)101-105

[51] Weizhi Tian, Bangfa Ni, Yangmei Zhang, Lei Cao, Metrological of Neutron Activation Analysis. II. Parametric INAA-an indeal back-up for INAA as a primary ratio method of measurement, Accred Qual Assur., Vol. 7 (2002)50-54

[52] Weizhi Tian, Bangfa Ni, Yangmei Zhang, Lei Cao, Metrological of Neutron Activation Analysis. IB. Inherent characteristics of relative INAA as a primary ratio method of measurement, Accred Qual Assur Vol.7 (2002)7-12

[53] Weizhi Tian, Bangfa Ni, Yangmei Zhang, Lei Cao, Metrological of Neutron Activation Analysis. IA. Inherent characteristics of relative INAA as a primary ratio method of measurement, Accred Qual Assur., Vol6 (2001)488-492

[54] Tian Weizhi, Ni Bangfa, Wang Pingsheng, Nie huiling, Cao Lei, Zhang Yangmei, Intercomparison and certification of some Chinese and international food and biological matrix CRMs for several uncertified ultratrace elements by NAA, J. of Radioanl. Nucl. Chem. Vol. 249 (1) (2001)25-28

[55] Ni Bangfa， Wang Pingsheng, Nie Huiling, Li Shuyuan, Liu Xuefeng, Tian Weizhi, Automation and computerization of NAA，J. of Radioanl. Nucl. Chem. Vol. 244(3) (2000)665-668

[56] Tian Weizhi, Ni Bangfa, Suitability of NAA for Certification of Reference Materials for Multielements，J. of Radioanl. Nucl. Chem. Vol. 245(1) (2000) 51-56.

[57] Ni Bangfa, Tian Weizhi, Nie Huining, Wang Pingsheng, He Gaokui, Study On Air Pollution In Beijing'S Major Industrial Areas Using Multielements In Biomonitors And Neutron Activation Analysis Techniques, Biological Trace Elements Research, Vol71-72 (1999) 267-272.

[58] Nie Huiling, Qin Linlin,Tian Weizhi, Ni Bangfa, Bao Ande, Wang Pingsheng, Preliminary Study Of The Relationship Between Osteoporosis And Trace Elements With Rat Models, Biological Trace Elements Research, Vol71-72 (1999) 623-628.

[59] Ni Bangfa, Study on air pollution around Chinese largest oil refinery complex using multielements in biomonitoring and NAA techniques, IAEA NAHRES-43, 1999

[60] Tian Weizhi, Ni Bangfa, Wang Pingsheng, Nie Huiling, Role of NAA in the Characterization of sampling behaviors of multiple elements in CRMs. Fresenius J. Anal. Chem., 360 (1998) 354.

[61] Bangfa Ni, Zhanqin Yu, Gaokui He, Pingsheng Wang, Weizhi Tian, NAA of two deep sea manganese nodule Rms for multielemets; J. Radioanal. Nucl. Chem., 215(1) (1997)77-79.

[62] Bangfa Ni, Zhanqin Yu, Gaokui He, Pingsheng Wang, Weizhi Tian, Multielemental NAA of geological micro-grain samples for origin identification, J. Radioanal. Nucl. Chem., 216(2) (1997)179-181.

[63] Qin Yali, Zhang Haiqin, Ni Bangfa, et al.,, Study on Black Carbon in Aerosol of Fangshan District, Beijing by Means of Reflection Method, Atomic Energy Science and Technology, 2010, Accept. (In Chinese)

[64] Yang Wei tao , Ni Bangfa, Wang Pingsheng, Tian Weizhi, et al., Element Composition Analysis of Airborne Particulate Matter (PM10 and PM2.5) by Instrument Neutron Activation Analysis, Atomic Energy Science and Technology, Vol.42(1) (2007) 228-231. (In Chinese)

[65] Liu Likun, Tian Weizhi, Wang Pingsheng, Huang Donghui, et al., Preliminary Study on Airborne Particulate Matter From Three Sampl ing Sites in Beijing Area by INAA, Journal of Isotopes, Vol.18 (1-2) (2005) 67-72. (In Chinese)

[66] Liu Likun, Ni Bangfa, Tian Weizhi , Wang Pingsheng, et al., Study on Correction Interference From 80 Brm in Neutron Activation Analysis of Br Using 80 Br as Indicator, Journal of Isotopes, Vol.18 (1-2) (2005) 79-83. (In Chinese)

India

[67] P.Kothai, I.V. Saradhi, P. Prathibha, P.K. Hopke, G.G. Pandit and V.D. Puranik, (2008), Source Apportionment of Coarse and Fine Particulate Matter at Navi Mumbai, India, Aerosol and Air Quality Research, Vol.8, No.4, pp 423-436

[68] P. Kothai, P. Prathibha, I.V. Saradhi, G.G. Pandit and V.D. Puranik, (2009), Characterization of atmospheric particulate matter using PIXE technique, International Journal of Environmental Science and Engineering, 1:1, pp 27-30

Indonesia

[69] Muhayatun, Diah Dwiana Lestiani, A. Markwitz, Philip K Hopke. Nuclear Analytical Techniques INAA and PIXE Application for Characterization of Airborne Particulate Matter in Indonesia, Journal of Applied Sciences in Environmental Sanitation (Volume V, Number N: 201-210, April-June, 2010)

[70] Muhayatun, Diah Dwiana Lestiani, Rita Mukhtar, Esrom Hamonangan, Halimah Syafrul, Andreas Makrwitz, Philip K Hopke Preliminary Study of The Sources of Ambient Air Pollution in Serpong Indonesia, Journal of Atmospheric Pollution Research, 2010 (accepted)

[71] Muhayatun Santoso, Philip K Hopke, Achmad H and Diah: “Sources identification of the atmospheric aerosol at urban and suburban sites in Indonesia by positive matrix factorization” Journal of Science and Total Environment 397, 229 – 237 (July 2008).

[72] Diah Dwiana, Muhayatun and Achmad H: Characterization of Black carbon in Fine Particulate Matter PM2.5 in Bandung and Lembang sites 2004-2005”, Indonesian Journal of Science and Nuclear Technology, Vol IX, No 2, August 2008.

[73] Muhayatun, Achmad Hidayat, Diah: “Ambient Air Concentration of PM2.5 and PM10 in Bandung and Lembang in 2000 - 2006”, Indonesian Journal of Science and Nuclear Technology, Vol IX, No 1, February 2008.

[74] Diah Dwiana, Muhayatun and Achmad H: “Temporal variation of fine and coarse particulate matter of 2005 – 2006” Indonesia Journal of Widyariset, Vol. 11(1), 239-245, 2008.

New Zealand

[75] W. J. Trompetter and A .Markwitz, "Air particulate research capability at the New Zealand Ion Beam Analysis facility using PIXE and IBA techniques", Intern. Journal of PIXE 15 (2005) 249

[76] A. Markwitz, "An overview of the RCA/IAEA activities in the Australasian region using nuclear analysis techniques for monitoring air pollution", Intern. Journal of PIXE 15 (2005) 271

[77] P. K. Davy, A. Markwitz, W. J. Trompetter and D. C. Weatherburn, "Elemental Analysis and Source Apportionment of Ambient Particulate Matter at Masterton New Zealand", Intern. Journal of PIXE 15 (2005) 225

[78] W. Trompetter, P. Davy and A. Markwitz, “Influence of environmental conditions on carbonaceous particle concentrations within New Zealand, J of Aerosol Science, DOI: 10.1016/j.jaerosci.2009.11.003

Malaysia

[79] Rahman, S.A., Hamzah, M.S., Wood, A.K., Elias, M.S., Salim, N.A.A., Sanuri, E., 2009. The application of factor analysis to identify sources in Klang Valley aerosol, Journal of Nuclear and Related Technologies 6(1), 279-286.

[80] Rahman, S.A., Hamzah, M.S., Wood, A.K., Elias, M.S., Salim, N.A.A., Sanuri, E., 2009. Chemical composition and source apportionment of aerosol over the Klang Valley, Nucl. Sci. J. Malaysia 21(1), 12-20.

[81] Rahman, S.A., Hamzah, M.S., Wood, A.K., Elias, M.S., Salim, N.A.A., Sanuri, E., 2010. Sources Apportionment of Fine and Coarse Aerosol in Klang Valley, Kuala Lumpur Using Positive Matrix Factorization. Submmited to Atmospheric Pollution Research.

Pakistan

[82] M. Wasim, A. Rahman, S. Waheed M. Daud and S. Ahmad, "INAA for the characterization of airborne particulate matter from the industrial area of Islamabad city", J. Radioanal. Nucl. Chem. 258(2) (2003) 397-402.

[83] S. Waheed, A Rahman, M. Daud, S. Rahman, Z. Islam, S. Ahmad "Air quality evaluation of some industrial cities of Pakistan using INAA and AAS" Radiochimica Acta., 93, (2005) 487-495.

[84] S. Waheed, A Rahman, N. Khalid and S. Ahmad, "Assessment of air quality of two metropolitan cities from Pakistan: Elemental analysis using INAA and AAS" Radiochim. Acta, 94 (2006) 161-166.

[85] S. Waheed, N Siddique, M. Daud, "Principle component analysis of air particulate data from the industrial area of Islamabad", The Nucleus, 45(3-4), (2008), 131-136

[86] Y. Faiz, M. Tufail, M. T. Javed, M. M. Chaudhry, N. Siddique, "Road dust pollution of Cd, Cu, Ni, Pb and Zn along Islamabad Highway, Pakistan", Microchemical Journal, 92, 186-192, (2009)

[87] S. Waheed, N. Siddique, Q. Hamid, M. M. Chaudhry, "Assessing soil pollution from municipal waste dump in Islamabad, Pakistan: a study by INAA and AAS", J. Radioanal. Nucl. Chem. 285, 723-732, (2010)

[88] S. Waheed, N. Siddique, Q. Hamid, "Analysis of municipal waste dump soil using a low power reactor: a study by instrumental neutron activation analysis", In-print, Radiochimica Acta, 98 (2010)

Sri Lanka

[89] M.C. Shirani Seneviratne; V.A. Waduge; Lakmali Hadagiripathira; S. Sanjeewani; T. Attanayake; N. Jayaratne; Philip K. Hopke. Characterization and Source Apportionment of Particulate Pollution in Colombo, Sri Lanka" (Manuscript ID: APR-D-10-00066R1) accepted for publication in Atmospheric Pollution Research in 2010

Vietnam

[90] Hien, P.D., Bac, V.T., Tham, H.C., Nhan, D.D., Vinh, L.D., Influence of meteorological conditions on $PM_{2.5}$ and $PM_{2.5-10}$ concentrations during the monsoon season in Hanoi, Vietnam. *Atmospheric Environment*, 36, p. 3473-3484 (2002).

[91] Hien PD, Bac VT, Thinh NTH, PMF receptor modelling of fine and coarse PM_{10} in air masses governing monsoon conditions in Hanoi, northern Vietnam. *Atmospheric Environment* 38 (2). pp 189-201 (2004).

[92] P.D.Hien, V.T.Bac & N.T.H.Thinh. Investigation of sulfate and nitrate formation on mineral dust particles by receptor modeling. *Atmospheric Environment* 39. pp 7231-7239 (2005).

[93] V. T. Bac & P. D. Hien. Regional and local emissions in red river delta, Northern Vietnam. *Air Qual Atmos Health* Vol.2, No.3, September, 2009. pp 157-167 (2009).

[94] Bac,V.T., Kregsamer,P., Markowicz, A., Elemental Sensitivity Method in XRF Analysis of PM_{10} Aerosol Filters. *Nuclear Science and Technology*. V.2, N.2, p. 18-28 (2003).

[95] V.T.Bac, N.T.H.Thinh. Source Identification of $PM_{2.5}$ at Lucnam, Bacgiang in 2001 by Receptor Modeling. *Nuclear Science and Tecnology*. V.4, N.1, p. 50-60 (2006).

Appendix 1

Table A1. Location and site description for the 14 RCA sampling sites within the IAEA/ RCA Project. The mass attenuation coefficient used to determine the BC carbon content of both fine and coarse GENT stacked filters is also included. Known sources obtained during positive matrix factorisation source apportionments are also listed.

Country	Site	Type	Longitude	Latitude	Techniques	Mass Atten Coeff (m^2/g)	Site Description	Known Sources
Australia	Lucas Heights	Rural	150.983	-34.052	PIXE, PIGE, PESA	7.0	30 km SW of Sydney centre, 16 km inland from the coast, extensive bushland, national parks to south and west for 45 km, urban housing 3 km to NE to west, local council garbage tip 2 km to the NW, only minor roads within 5 km of site.	Soil, Sea salt, Autos, Smoke from biomass burning
	Liverpool	Urban	150.925	-33.925	PIXE, PIGE, PESA	7.0	15 km NNW of the Lucas Heights site, surrounded by urban housing and light industry for 10 km in most directions including a significant railway line within 1 km, nearest significant bushland >12 km to the south.	Autos, 2ndryS, Soil, Sea salt, Industry, Smoke.
Bangladesh	Dhaka	Urban Semi-Residential	90.40E	23.73N	PIXE, PIGE	9	Semi-residential in Dhaka city, ~300 km from the sea in the South, 80 m away from road roadside with moderate traffic. Dhaka city is characterized by high traffic congestion and small industries and large number of brick kilns around.	Road dust, Soil dust, Automobiles, Metal Smelter/Industry Sea salt, Zn source Brick kiln/Biomass burning Construction
China	Urban	Urban	116.32 E	39.93 N	INAA	?	In downtown, represent a heavy traffic site in downtown	Soil and fly ash， refuse incineration, limestone,

								motor vehicle exhaust, coal burning.
	Site1	Suburban	115.98 E	39.72 N	INAA	?	Installed in a middle school, represent a residential site in suburb	Soil and fly ash , limestone, motor vehicle exhaust refinery and combustion.
	Site2	Suburban	116.01 E	39.71 N	INAA	?	Installed in a square , represent a traffic site in suburb	Soil and fly ash , limestone, motor vehicle exhaust, refinery and combustion
India	Trombay	Suburban	73.02 E	19.05 N	INAA,EDXRF, PIXE	5.93	Trombay -industrial area hill on one side and sea on other side	Soil, industrial , sea salt, vehicle
	Vashi	Suburban				5.93	Vashi-industrial area 1km from national high way	Soil, industrial , sea salt, vehicle
Indonesia	Bandung	Urban	107.60	-6.91	PIXE, NAA	5.27	630 m above sea level. It is the provincial capital of West Java and is categorized as an industrial city with a population of more than 2.6 million inhabitants in an area of approximately 167.67 km2. Many small scale factories are also located around the city.	Soil, seasalt, motor vehicles, biomass burning road dust, and secondary sulfur
	Lembang	Suburban	107.23	-6.79	PIXE, NAA	5.27	Sampling at the suburban site was conducted in Lembang on the roof of the Meteorological and Geophysical Agency's building about 6 m above ground level and about 1 km from the nearest major street. Lembang is a small village about 16 km from sampling site in Bandung, 1300 m	Soil, seasalt, motor vehicles, biomass burning and road dust

							above sea level, close to the Boscha observatory	
Korea	Daehwa	Urban	127.22	36.26	INAA	7.14	One of big industrial sampling sites, which mainly consists of more than 100 different types of business.	1) small scale industries producing metallurgical, mechanical, rubber/plastic, and chemical products 2) large scale industries dealing with soaps and cosmetics 3) large scale cement/plaster factories
	KAERI	Suburban	127.25	36.22	INAA	7.14	A suburban sampling site, KAERI, is located about 1km northward from the heavy-traffic intersection of the four-lane Honam highway and six-lane local road.	1) two municipal waste incinerators 2) power station 3) chemical industries 4) agricultural activities
Malaysia	Klang valley	Urabn	101.7 E	3.17 N	PIXE, INAA	9.7	Most busy area with about 5 million population, home, industry, factories, and residential area	Soil dust, road dust, motor vehicle sulphur, biomass burning
Mongolia	Ulaanbaatar	Urban	106.58	47.54	PIXE, PIGE	5.7	5 km E of Ulaanbaatar centre, surround dwelling houses, 200 m from main road(S and SW)	Soil, Coal combustion (smoke), ,wood burning Road and

								construction Dust and motor vehicle
New Zealand	Masterton	Urban	175.660	-40.933	PIXE, PIGE, PESA	?	In the city centre, small population, 65 km away from the Cook Strait to the south-west, 50 km away from the sea to the North-west, >500 hill in 25 km distance to the NW and NE, prevailing wind directions: NW and S. Calm winter days	Biomass burning, sea spray, soil, motor vehicles
	Seaview	Urban	174.914	-41.240	PIXE, PIGE, PESA	?	Industrial area of Lower Hutt, only 1 km away from Wellington harbour to the south, urban housing about 1.5 km away to the north-west, prevailing wind directions: NW and S. Strong exposure to marine aerosols.	Soil, sea spray, biomass burning, motor vehicles, industry
	Wainuiomata	Urban	174.953372	-41.268027	PIXE, PIGE, PESA	?	Wainuiomata is a residential area located in a valley basin surrounded by hills ~200 m high to the north and west, to the east the hills rise into the Rimutaka Range up to ~800 m high. The south end of Wainuiomata narrows to a constricted valley which runs 20 km down to the ocean. Wellington City is 15 km to the southwest across the hills and harbour.	Soil, sea spray, biomass burning, motor vehicles
Pakistan	Nilore Islamabad	Sub Urban	33° 43’ N,	73° 03 E	INAA, PIXE, PIGE, PESA	7	Located on the Potohar Plateau in the northwest of Pakistan. Has small industrial area with numerous brick kilns in suburbs. Since located on a plateau surrounded by mountains on two sides, which confine pollutants in this area leading to high SPM leading to problems like reduction in visibility and different forms of allergies. The Nilore area has a university and 2 research institutes, with a	Suspended soil, dust and automobiles sources. Sources of Sea salt are probably long range.

							small residential colony and a fleet of about 500 vehicles including buses, cars, wagons, trucks and motor cycles.	
	Airport Housing Society Rawalpindi	Urban Residential	33°36´ N	73°02´E	PIXE, PIGE, PESA	?	Located on the Potohar Plateau in the south of Islamabad. City is home to many industries and factories; steel mills, marble factories, soap/ chemical factories, ceramics, paint and pharmaceutical manufacturing plants, and several other small industries. A number of brick kilns are also operating in the vicinity of the area. Has international airport in the vicinity.	Soil, automobile and brick kiln whereas road dust, construction and 2 stroke are the minor sources.
Philippines	Ateneo de Manila University	Urban/ Residential	121.077	14.636	PIXE	7.0	Located at the Ateneo de Manila University Campus, on the eastern part of Metro Manila. It is adjacent to major subdivisions and overlooks the Marikina Valley. The campus is bounded on the left by the Katipunan road which gets very busy especially on school days. It is co-located with the EMB real-time monitoring station.	Vehicular emission, biomass burning, secondary S, soil, sea salt, industry.
Sri Lanka	AEA	Urban +Diesel power plant	79 ^{0} 51’45E	6 ^{0} 49’35N	XRF	?	10 km NE of Colombo city centre, 10 km inland from the coast, Small housing 3 km to west, local council garbage dumping site is located to2 km to the NW from the site , 1 km West of Diesel- electricity power plant. West of Main road running to Colombo city	Soil, Sea spray, Secondary Sulphate smoke
	AQM	Urban	79 ^{0} 86’E	6 ^{0} 9’N	XRF	?	Commercial city, surrounded by commercial stores urban housing ,railway line and Colombo harbour with in 2 km. Main bus stand is situated within 3 km to north.	Soil , Vehicular emissions, Secondary sulphate, seas spray.
Thailand	Pathumwa	Urban	100.49 E	13.75	INAA	5.7	Capital city, Curbside at downtown	Autos, Soil,

	n, Bangkok						center, skytrain and tollway at the site, urban housing-university-school-shopping and business buildings, small industrial factories (mainly cement, metal plated and textile) within Bangkok area (1500 km^2) in most directions.	Sea salt, Construction
	Chatuchak, Bangkok	Urban	100.57 E	13.85	INAA, PIXE	5.7	Capital city, residential area surrounded by house-flat-building-university-school, a toll way 300-500 meters in the SW to NW of sampling site, railway behide the toll way further in the SW to NW of sampling site about 40 km from the Gulf of Thailand.	Autos, Soil, Sea salt, Cement/Construction, Smoke from biomass burning, SO_4, high Zn
	KlongHa, Pathumthani	Suburban	100.74 E	14.04	INAA, PIXE		Pathumthani is Bangkok's boundary in the north. A suburb, residential area surrounded by houses (wooden & brick)-canal-tree and grass field, the site is in a government science center, a major road about 5 km in the south	Soil, Sea salt, Cement, Smoke from biomass burning, SO_4,
Vietnam	Lang-Hanoi	Urban	105.85	21.02	PIXE, PIGE, PESA	7.0	5 km SW of Hanoi centre, about 100 km west of the East China Sea and about 150 km to the borders with China and Laos.	Soil, Sea salt, Autos, Smoke from biomass burning, 2ndryS, Industry.

Appendix 2

Table A2. Summary of participating country dataset inputs.

All countries all sites fine PM2.5 filters

Site#	START	STOP	Mass>0	Err=9	Err%	Elts>0	Al>0	Si>0	S>0	BC>0	BCErr>0	BCMDL>0	Elts
AUS33	01-Jan-03	02-Nov-08	594	19	3.2	594	573	594	594	592	594	594	21-21
AUS35	01-Jan-03	02-Nov-08	594	39	6.6	594	565	594	594	574	594	594	21-21
BAN880	02-Jan-02	28-Feb-07	448	26	5.8	448	448	448	448	448	448	448	18-29
CHN86	07-Jan-02	13-May-04	79	32	41	79	79	0	14	0	0	0	22-36
CHN86a	23-Mar-04	09-Oct-06	133	29	22	133	114	0	41	0	0	0	10-37
CHN86b	20-Nov-03	16-Jun-08	314	29	9.2	314	307	65	200	65	65	65	10-37
IND91a	01-Jan-02	14-Nov-07	362	7	1.9	362	362	362	362	361	354	362	7-33
INO62	13-Jan-03	09-Dec-09	605	95	16	601	556	431	431	600	600	602	1-33
INO62a	13-Jan-03	25-Jun-09	573	151	26	570	547	425	427	566	566	573	1-33
KOR82	05-Jan-02	30-Nov-07	490	100	20	490	486	0	0	490	490	490	8-24
KOR82a	05-Jan-02	11-Dec-08	583	88	15	583	570	0	0	583	583	583	11-24
MAL60	08-Jan-02	22-Dec-08	228	39	17	228	228	228	228	228	228	228	21-21
MON73	25-Oct-04	30-Nov-08	302	7	2.3	302	301	302	302	302	302	302	33-33
NZ64c	15-Jul-05	29-Jun-07	142	20	14	142	142	142	142	138	138	142	32-32
NZ64b	05-Jul-02	10-Jan-04	77	10	13	77	77	77	77	77	77	77	32-33
NZ64e	01-Sep-06	25-Sep-08	222	7	3.2	222	218	222	222	144	144	222	32-32
PAK92	17-Apr-02	19-Apr-07	477	248	52	476	460	336	336	476	476	477	1-33
PHI63	16-Jan-01	26-Dec-07	651	20	3.1	651	650	651	651	651	651	651	21-21
SRI94	18-Jun-03	26-Feb-08	229	4	1.7	227	223	226	226	227	227	227	28-38
SRI94a	04-May-00	15-Aug-07	237	14	5.9	234	225	233	233	234	233	234	26-38
THA66	02-Jan-02	30-Dec-07	556	6	1.1	556	556	485	485	556	556	556	19-26
THA66a	15-Jan-03	30-Dec-07	425	46	11	425	425	401	401	425	425	425	19-25
VIE84	16-Jan-02	24-Dec-08	460	32	7.0	460	439	460	460	460	460	460	21-21
		Total	**8,781**	**1,068**		**8,768**	**8,551**	**6,682**	**6,874**	**8,197**	**8,211**	**8,312**	
		%	**100**	**12**		**99.9**	**97**	**76**	**78**	**93**	**94**	**95**	

Cells with zeros or very low numbers highlighted in red are possible problem areas

All countries all sites coarse (2.5-10µm) filters.

Site#	START	STOP	Mass>0	Err=9	Err%	Elts>0	Al>0	Si>0	S>0	BC>0	BCErr>0	BCMDL>0	Elts
AUS33	1-Jan-03	2-Nov-08	594	54	9.1	594	586	594	594	507	594	594	21-21
AUS35	1-Jan-03	2-Nov-08	594	60	10	594	571	594	594	484	594	594	21-21
BAN880	2-Jan-02	28-Feb-07	449	46	10	449	449	449	449	0	0	0	12-27
CHN86	7-Jan-02	13-May-04	77	33	43	77	76	0	0	0	0	0	23-37
CHN86a	23-Mar-04	9-Oct-06	131	44	34	131	112	0	0	0	0	0	10-40
CHN86b	20-Nov-03	16-Jun-08	296	45	15	296	296	65	64	0	0	0	17-40
IND91a	1-Jan-02	14-Nov-07	362	7	1.9	362	362	362	362	238	210	244	7-34
INO62	13-Jan-03	9-Dec-09	600	90	15	595	581	437	441	586	586	596	1-33
INO62a	13-Jan-03	25-Jun-09	572	111	19	562	550	410	411	553	554	562	1-33
KOR82	5-Jan-02	30-Nov-07	490	136	28	490	486	0	0	0	0	0	10-24
KOR82a	5-Jan-02	11-Dec-08	583	198	34	583	583	0	0	0	0	0	9-24
MAL60	8-Jan-02	22-Dec-08	228	62	27	228	228	228	228	228	228	228	21-21
MON73	25-Oct-04	30-Nov-08	302	6	2.0	302	301	301	301	301	301	301	33-33
NZ64c	15-Jul-05	29-Jun-07	151	98	65	151	151	151	151	151	151	151	33-33
NZ64b	5-Jul-02	10-Jan-04	87	10	11	87	87	87	87	87	87	87	33-33
NZ64e	1-Sep-06	25-Sep-08	187	42	22	187	187	187	187	185	185	187	33-33
PAK92	17-Apr-02	19-Apr-07	477	222	47	477	464	337	337	477	477	477	1-37
PHI63	16-Jan-01	26-Dec-07	651	31	4.8	651	651	651	651	651	651	651	21-21
SRI94	18-Jun-03	26-Feb-08	227	51	22	202	0	7	43	200	0	203	9-18
SRI94a	4-May-00	15-Aug-07	212	53	25	194	0	3	22	194	0	193	10-17
THA66	2-Jan-02	30-Dec-07	556	23	4.1	556	556	180	180	556	556	556	11-24
THA66a	15-Jan-03	30-Dec-07	425	29	6.8	425	425	163	163	425	425	425	19-24
VIE84	16-Jan-02	24-Dec-08	460	108	23	460	460	460	460	0	0	0	20-20
		Total	**8,711**	**1,559**		**8,653**	**8,162**	**5,666**	**5,725**	**5,823**	**5,599**	**6,049**	
		%	**100**	**18**		**99**	**94**	**65**	**66**	**67**	**64**	**69**	

Cells with zeros or very low numbers highlighted in red are possible problem areas