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The IAEA/RCA Fine and Coarse PMF Receptor Fingerprint Database

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Abbreviations

Abbreviation	Description
ANSTO	Australian Nuclear Science and Technology Organisation
A-PAD	Asia-Pacific Aerosol Database
AUS	Australia
BAN	Bangladesh
BC	Black Carbon
CHN	China
CSIRO	Commonwealth Scientific Industrial and Research Organisation
EPA	Environmental Protection Agency
IAEA	International Atomic Energy Agency
INAA	Instrumental Nuclear Activation Analysis
IND	India
INO	Indonesia
KOR	Korea
MAL	Malaysia
MDL	Minimum Detectable Limit
ME	Multilinear Engine
MON	Mongolia
NAT	Nuclear analytical technique
NZ	New Zealand
PAK	Pakistan
PHI	Philippines
PIXE	Particle Induced X-ray Emission
PMF	Positive Matrix Factorisation
PMF	Particulate Matter
RCA	Regional Cooperative Agreement
SRI	Sri Lanka
THA	Thailand
VIE	Vietnam
XRF	X-ray Fluorescence

1. Introduction

This document accompanies the IAEA Master Positive Matrix Factorisation (PMF) Databases (fine and coarse). These databases have been generated from the 14 member state RCA 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 PMF database with explanatory notes by February 2016 to the IAEA.

The aim of this document is to provide instructional steps and related information necessary for navigating and utilising the IAEA Master Positive Matrix Factorisation (PMF) databases. It is important to note that interpretation of the PMF fingerprints and apportionment contained in either the coarse or fine databases are beyond the scope of this document. However, several countries have already published peer-reviewed papers related to their sites PMF source fingerprinting and source apportionment results. Comprehensive lists of publications are provided in **Appendix 2**.

2 Elemental database (A-PAD)

2.1 What is the Asia-Pacific Aerosol Database (A-PAD)?

The A-PAD is a comprehensive multi-elemental characterisation database comprising both fine and coarse airborne particle data generated by 14 IAEA member states from across the greater Asia-Pacific region, sampling for 24 hours once a week over the period of 2003 - 2013. The participating member states 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). The A-PAD is a unique database resource which is already proving useful to pollution managers and to researchers alike and we believe will be a valuable resource for many years to come. Currently, we are not aware of any other dataset of fine and coarse particulate matter measurements with nuclear multi-elemental analyses and spanning at least 10 years and 14 countries in the Asia-Pacific Region.

2.1.1 Sampling and sampling sites

Each member state utilised the same GENT aerosol unit to collect airborne particulate matter (PM) samples [1]. The GENT sampling unit is a stacked filter system collecting two PM size fractions on polycarbonate filters; fine particulate matter with aerodynamic diameter less than 2.5 µm ($PM_{2.5}$) and coarse particulate matter from 2.5 µm to 10 µm ($PM_{2\text{-}5\text{-}10}$). Sampling by each member state was performed at least once per week over a 24 hour period. Typical flow rates in the GENT system were nominally approximately 16 L/min. A map of the site locations is provided in **Figure 1**. A table of sampling site descriptions is provided in **Appendix 1**.

Figure 1 Map showing the location of sampling sites across the Asia-Pacific region involved in this project

Figure 2 shows a plot of the start and stop sampling dates for each site and each member state. It clearly shows that, for at least one site in each member state, there is a data set spanning a 10 year period between January 2003 and December 2013 for many of the 14 participating countries. Several countries had more than one site operational during the study period. This was not necessarily a good thing as the ideal situation would have been to be sampling at the one site the whole time. 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 **Figure 2** (see AUS, CHN, INO, KOR, SRI and THA for example).

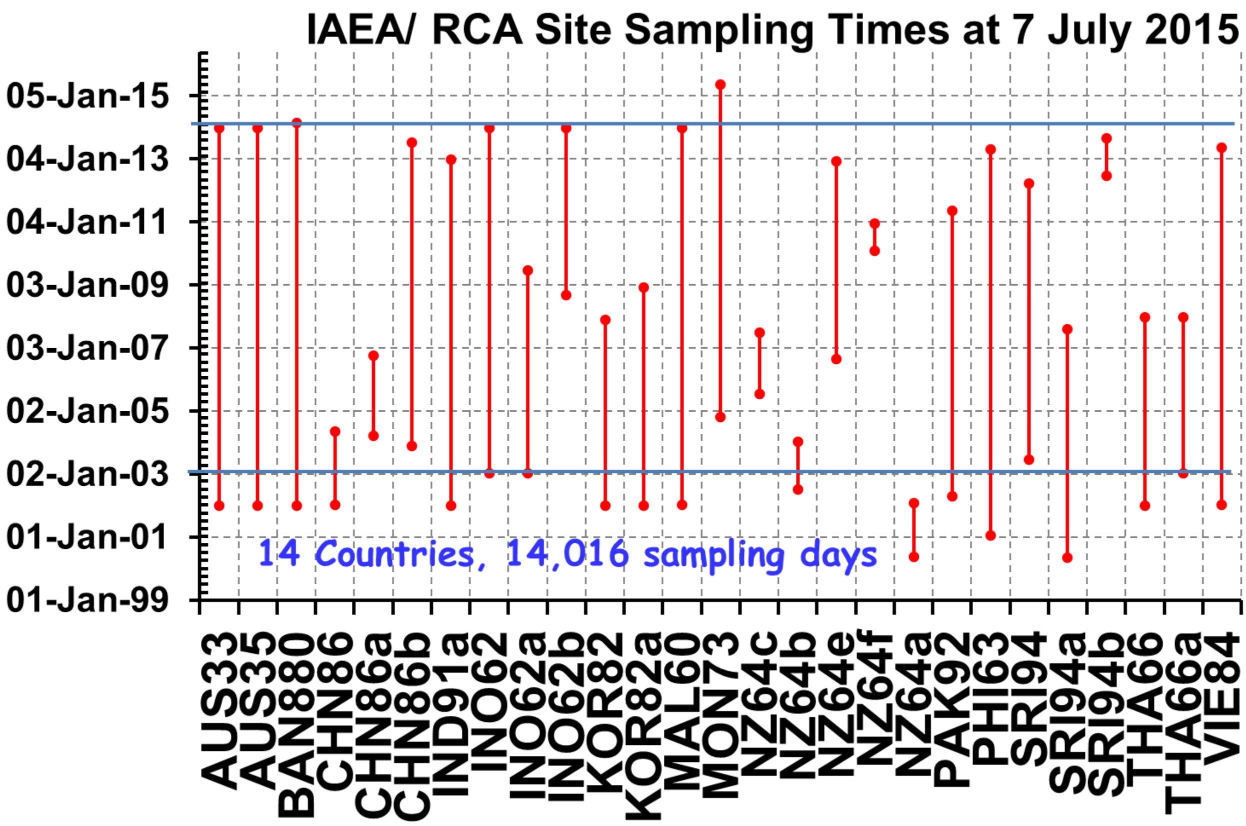

Figure 2 Timeframe for each site spanned by the A-PAD database. The numbers at the end of each member state label on the x-axis represent the internally designated sampling site numbers for that member state or if they had none, their member state phone code (with a letter a, b, c ...) was used to distinguish the different sites in the same member state.

2.1.2 Sample analysis

Gravimetric Mass

Individual filters samples for each site were weighed in their respective countries using a microbalance both pre and post-exposure to determine the gravimetric fine particulate mass loading in micrograms (µg).

Black Carbon

Fine filters were measured for black carbon (BC) in their respective countries using the Smoke Stained Reflectometry method with an assumed mass absorption coefficient, ε (m^2/g) which generally ranged from 5 m^2/g to 10 m^2/g. It should be noted that this measurement 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 [2]. Therefore, caution should be exercised in utilising coarse BC values contributed to the A-PAD by some member states.

Elemental Analysis

Each collected filter sample was analysed using the nuclear analytical technique/s (NAT) available in that specific member state. NATs included particle induced X-ray emission (PIXE), x-ray fluorescence (XRF) and instrumental nuclear activation analysis (INAA). In general, these techniques provide elemental concentrations ranging from fluorine (Z=9) to uranium (Z=92). Therefore, the set of species analysed on each filter and included in the A-PAD by each member state ranged from 17 to 40 depending on the NATs techniques applied. Ideally, the range of elements determined by each member state should aim to at least span the commonly expected sources such as sea spray, soil, automobiles, secondary sulfate etc. – this was the case for most member states.

The A-PAD dataset is well suited for use in source apportionment studies which require typically 10 or more independent elements that span the range of expected sources, as well as associated error and minimum detectable limit (MDL) values. All of which are provided in the A-PAD.

3. Positive Matrix Factorisation (PMF) Database

The A-PAD described in section 2 was then utilised by each participating member state to generate a set of receptor source fingerprints and related apportionment for their site/s using statistical the Positive Matrix Factorisation (PMF) technique.

3.1 What is Positive Matrix Factorisation (PMF)?

The PMF technique is capable of statistically correlating the measured elemental data contained in the A-PAD into fingerprints that represent key pollution sources at the receptor site and their contributions to the total particulate matter mass. It should be noted that the original DOS version of the PMF analysis codes developed by Paatero [3-5] was used in this work and not the modified US-EPA PMF codes based on multi-linear engine (ME) available on the internet. We utilised the PMF-DOS version as it is a more flexible code designed for researchers. In addition, the participants from Australia have invested significant time developing VBA software scripts for running this code as well as standardising and plotting many of its output files in Excel. A recent collaborative study [6] involving ANSTO and CSIRO in Australia showed very good agreement in the PMF solutions obtained independently using the two different PMF versions. This is important as the solutions to equations utilised in PMF are NOT unique, but are produced by a least squares iterative process based on the following matrix equation:

$$X = F \times G + E \tag{1}$$

where X(n,m) is a measurement matrix of n samples (i.e. elemental database dates or rows) and m chemical species (i.e. elemental database columns), F(p,m) is a factor matrix of p factor fingerprints each with m elements, G(n, p) is a contribution matrix of the p source fingerprints for each of the n samples, and E(n, m) is an error matrix which is minimised during the PMF process. The PMF codes work statistically towards minimising the unexplained part of the X(n,m) matrix. What differentiates PMF from other statistical source apportionment methods such as chemical mass balance (CMB) or principal components analysis (PCA) is that the G and F matrices are constrained to positive values only. The error term matrix, E(n,m) is reduced in the PMF process by minimising the Q value:

$$Q = \sum_i \sum_j \left(\frac{e_{ij}}{s_{ij}}\right)^2 \tag{2}$$

where eij are the elements in the error matrix term E and sij are the estimated errors of the experimental measurements assessed by the PMF process. In our case, we used:

$$s_{ij} = Err_{ij} + MDL_{ij} \tag{3}$$

where Err and MDL are the error and minimum detectable limit values, respectively.

The PMF analysis will generally be performed multiple times for each site with a varying number of source fingerprints or factors (p) in order to determine and compare the best statistical fit while maintaining a solution that meets the following criteria: all average factor contributions are greater than 1 %, all factors are positive, all regression coefficients are positive, all P-values are less than 0.05 and χ^2 close to unity, where:

$$\chi^2 = Q / Q_{theory} \tag{4}$$

and

$$Q_{theory} = mn - p(m+n) \tag{5}$$

and Q is calculated by the PMF codes and is given by equation (2) above.

The IAEA master PMF database contains what each member state believes to be their best factor elemental fingerprint solution, daily fingerprint concentrations (in ng/m^3), daily factor contributions to total pollution (in % of total mass) and associated fingerprint errors.
It should be noted that PMF analysis process does not automatically assign a receptor source name to each resulting fingerprint. It only provides the fingerprints and their contributing correlating elements. Each fingerprint is then given a suitable name by the data analyst based on local sampling site knowledge and experience in identifying the most likely source associated with the elemental fingerprint of each factor. For example, a factor dominated by Al, Si, Ca, Ti and Fe in the elemental fingerprint is typically associated with windblown soil, or H and S or Na and Cl present in a factor in the correct ratios can be used to identify a secondary sulfate and sea spray factor, respectively.

3.2 The IAEA/RCA Fine and Coarse PMF Fingerprint Database Macros

The IAEA Master PMF fingerprint databases (fine and coarse) are provided as the following macro-enabled excel files: "*FINE_MasterPMFdatabase-15Feb2016.xlsm*" and "*COARSE_MasterPMFdatabase-15Feb2016.xlsm*". In an effort to reduce the size of these database files, they only contain the PMF data (without the associated plots) from each of the contributing member states. Excel VBA macro functions are then utilised to automatically generate the associated PMF plots for each site as required. These macro functions are accessed from the Menu page and their use and function described in the following sections of this document. Please note: these macro functions have been written and tested to operate correctly in Excel version 2007-2010.

Important: Depending on your Microsoft Excel settings, you may encounter a "Security Warning Macros have been disabled" alert when you open the PMF Master database files (see **Figure 3**). You will need to press the "Enable Content" button for the macros to function correctly.

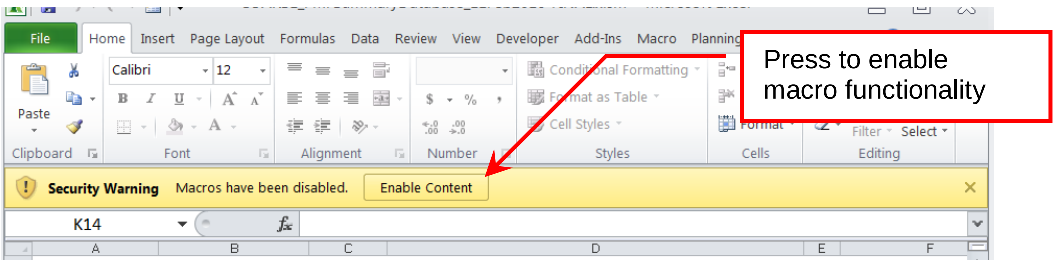

Figure 3 Microsoft Excel macro security warning and enable content button

3.2.1 Initialising the Program

When you open each Excel database (coarse or fine) for the first time, you will land on the "Menu" worksheet (See **Figure 4**). For convenience, a brief version of instructions is also available at the top of this page. To begin using the database, the program must first be initialised. This process clears any previous data and plots and also prepares the required macro functionality. Initialisation is performed by pressing the button labelled **"(1) INITIALISE DATABASE**" (see **Figure 4**).

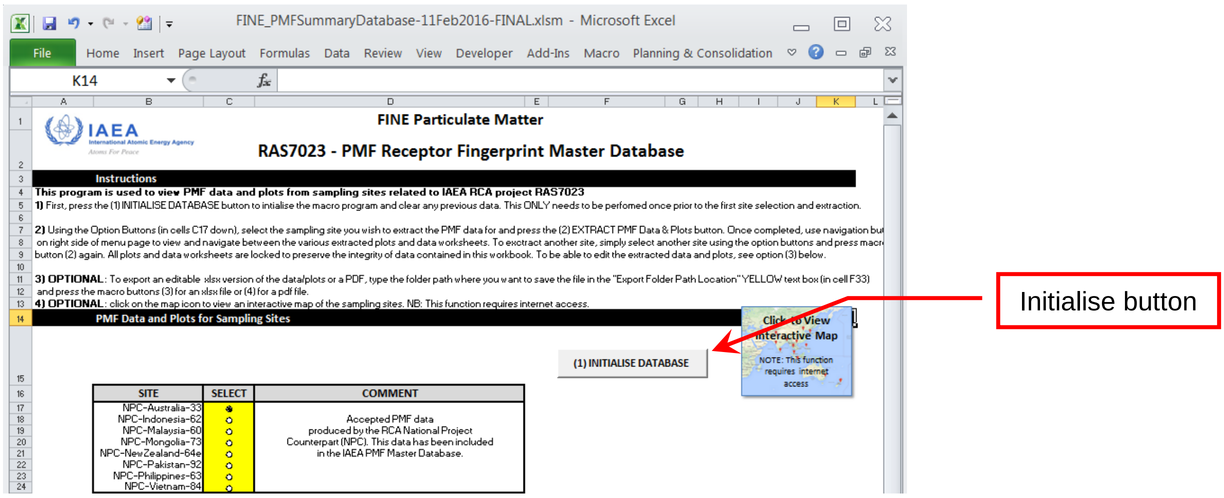

Figure 4 Section of the Menu page showing the location of the INITIALISE DATABASE button

3.2.2 Extract PMF Data and Plots

After the database macro has been successfully initialised, you will see that it generates an additional button **"(2) EXTRACT PMF Data & Plots**". Before pressing this button, you must first select which sites data you would like to extract. This is done by pressing one of the selection buttons in the yellow coloured "SELECT" column (see **Figure 5**). Please note, only one site can be selected for extraction at a time.

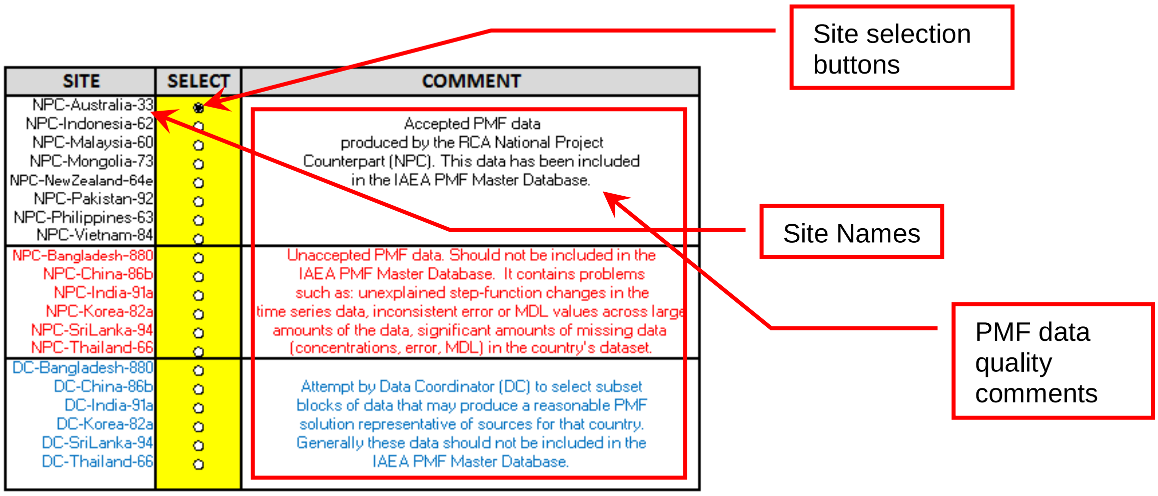

Figure 5 Section of the Menu page showing the SITE name, SITE SELECTION buttons and related COMMENTS

Once a site has been selected, press the **"(2) EXTRACT PMF Data & PLOTS**" button (see **Figure 6**). Depending on the amount of data for the selected site and processing speed of your computer, the data extraction and plotting may take up to a minute to complete. For convenience, a progress bar will be shown in the bottom left corner of the excel window during the extraction process.

Site Names

The names of the sites are listed in the column labelled "SITE" (see **Figure 5**). The first characters in the name denote whether the analysis was performed by the National Project Counterpart (NPC) or the Data Coordinator (DC). This is followed by a hyphen and then the country name of the member state. This is followed by another hyphen and the site number. For example, "NPC-Australia-33" denotes PMF analysis performed by the National Project Counterpart (NPC) of Australia on their sampling site number 33.

PMF Data Quality Comments

It is important to note at this point that the PMF data for each site in the table (see **Figure 5**) have been grouped according to a quality assessment of their final PMF results as follows:

1) The first group of PMF results (with font color-coded **BLACK**) denote PMF data which has been produced by the National Project Counterpart (NPC) for that site, submitted to the Data Coordinator (DC), and the PMF results assessed to be of a suitable quality for inclusion in the IAEA PMF Master Database. This group of PMF data represents the IAEA PMF Master Database set.

2) The second group of PMF results (with font colour-coded **RED**) denote PMF data which has been produced by the National Project Counterpart (NPC) for that site, submitted to the Data Coordinator (DC), but the results assessed to be of a quality not acceptable for inclusion in the IAEA PMF Master Database set. They are however still shown in the database file for completeness but caution should be exercised when interpreting this PMF data. Problems with this PMF data may include:
    i. Significant unexplained and largely unrealistic step-function changes observed in the time series data and plots for one (or more) fingerprints (see **section 3.3.3 and 3.3.4**). For example, this may be caused when the utilised nuclear analysis technique (NAT) was changed or not available at a site during the analysis period. This can result in either the loss/gain of certain elemental species, or cause significant sensitivity changes (e.g. up to orders of magnitude) which in turn changes their reported concentration in the A-PAD – both of which can artificially produce step-function changes which are not true indications of changes in environmental air particulate receptor sources at the site. Consequently, this data has not been included in the IAEA PMF Master Database and caution exercised when viewing this PMF data.
    ii. Inconsistent/missing ERROR or MDL values in the associated A-PAD for that site across large amounts of data. Similar to (a) above, inconsistent or missing errors and MDLs in the A-PAD can drive artifical step changes in the time series of an identified fingerprint. In addition, they may also artifically weight the accuracy and significance of a particular specie/s which can force the production of unrealistic fingerprints. Consequently, this data has not been included in the IAEA PMF Master Database and caution exercised when viewing this PMF data.

3) The third group of PMF results (with font colour-coded **BLUE**) denote PMF data produced by the Data Coordinator (DC) for sites with unaccepted or missing PMF data generally using a subset block of A-PAD data for the site in an attempt to obtain a reasonable PMF solution. As this solution has not been performed by the NPC with their specific local site knowledge and often with a significantly reduced dataset, it has not been included in the IAEA PMF Master Database set and only shown for completeness/comparison but caution should be exercised when interpreting this PMF data.

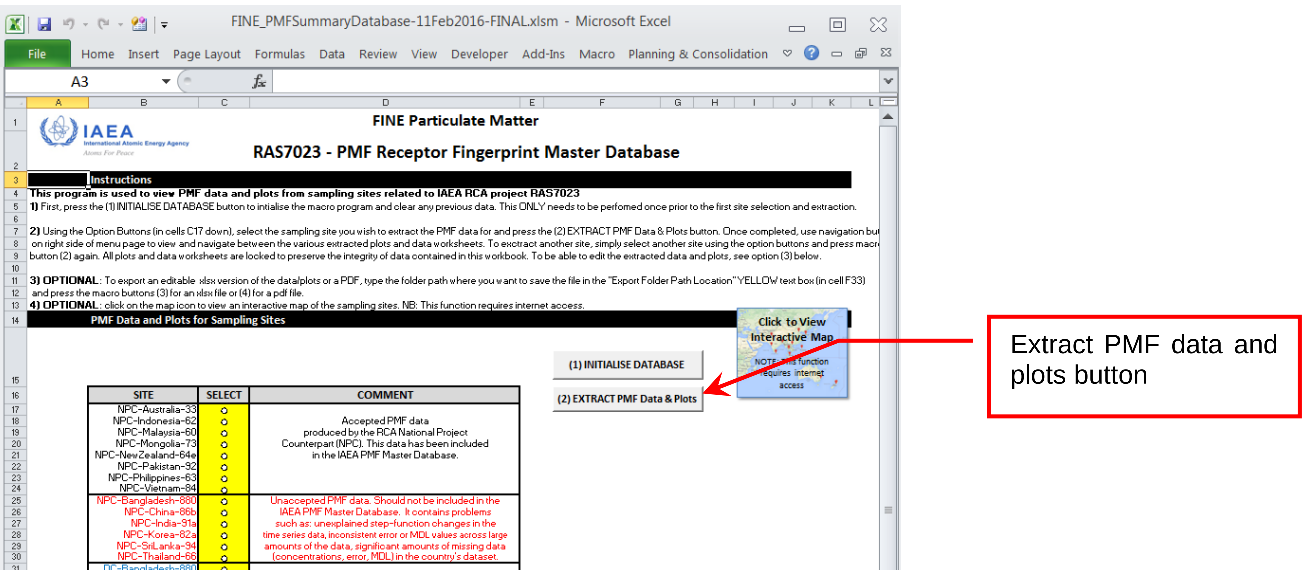

Figure 6 Section of the Menu page showing the location of the EXTRACT PMF Data & Plots button

Once the extraction is complete, the Menu worksheet will be updated with additional SUMMARY INFORMATION, worksheet navigation buttons and file export buttons (see **Figure 7**).

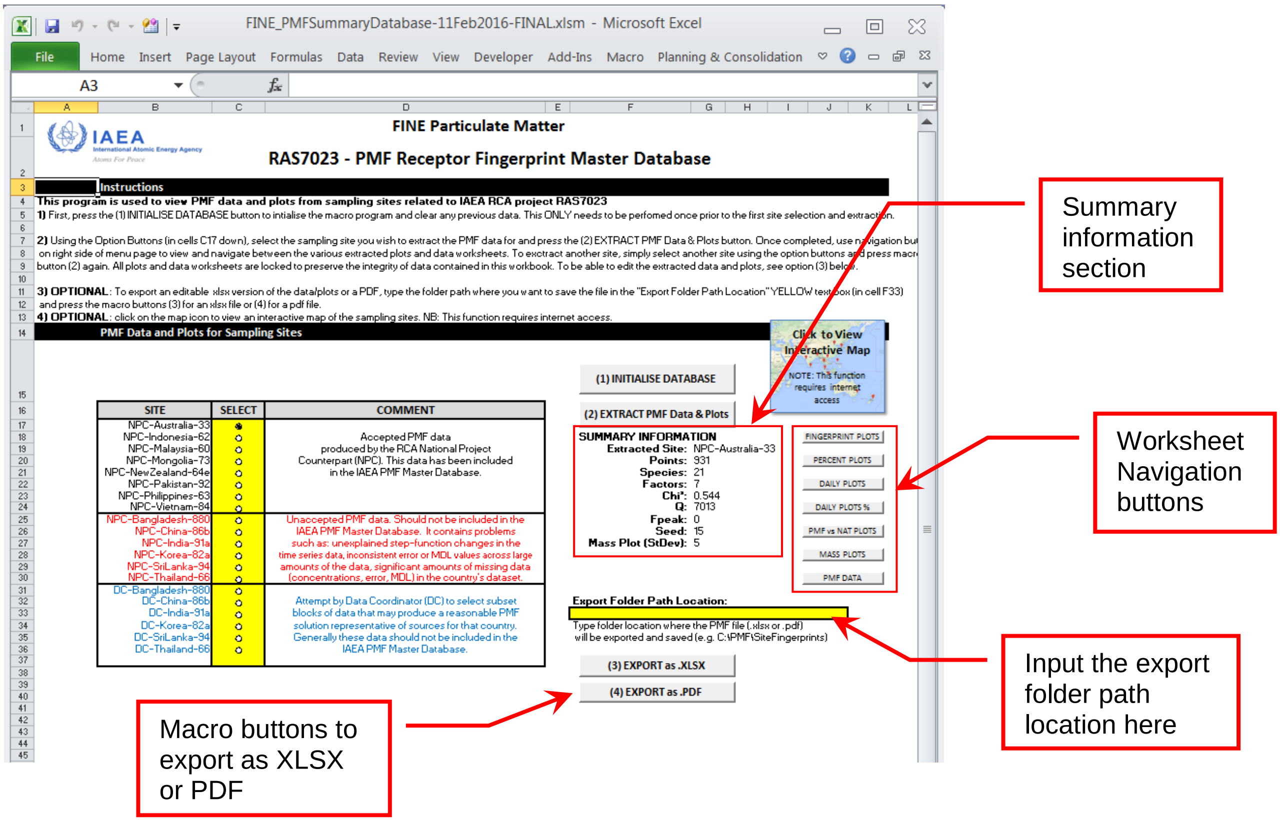

Figure 7 Location of SUMMARY INFORMATION, worksheet navigation buttons, xlsx and pdf file export text box and buttons on Menu page

This summary information provides the following details: the extracted site, number of points (i.e. sampling days) used in the PMF analysis, number of species (or elements) used in the PMF analysis, number of fingerprints obtained with PMF analysis, chi-squared (χ^2) value, the Q-value, F-peak value, Seed value and the number of standard deviations used for the tramlines on the Mass Plot (see **Figure 8**).

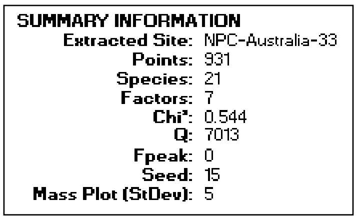

Figure 8 Section of Menu page showing summary information section of the Menu page

The Menu worksheet will also be updated with additional navigational buttons which can be used to go between the various extracted data and plot sheets (see **Figure 9**). These navigation buttons are also available on each of the generated worksheet.

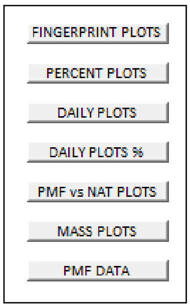

Figure 9 Worksheet navigation buttons panel

3.2.3 Export Data and plots as xlsx or pdf

XLSX
At this point, using the navigational buttons the data and plots can be viewed within the database macro. However, all of the contained worksheets are **locked** and cannot be edited. This is to maintain the integrity of the data contained in the database program itself. If you would like to edit the extracted data or plots (for example, to re-plot the data in another program), you will need to export the extracted data as an **unlocked** xlsx file. To do this, type an existing folder path location where you would like this .xlsx file to be exported to in the yellow colored cell F33, for example, "C:\PMF\Australia\fingerprints". Now press the macro button "**(3) EXPORT as .XLSX**" to export the file (see **Figure 10**). The filename of the exported xlsx file will be automatically generated as the selected site name. This xlsx file will contain the following: a summary information cover page (CoverPage) (see **Figure 11)**, worksheet containing the PMF data (named as the site that was extracted), worksheet of fingerprint plots (FingerprintPlots), worksheet of percent plots (PercentPlots), worksheet of daily plots (DailyPlots), worksheet of daily plot percent (DailyPlots%), worksheet of PMF Mass vs gravimetric Mass plots (MassPlots) and a worksheet of PMF vs NAT plots for each specie.

PDF
To export a pdf file, follow the same process described above for the xlsx file but press the macro button "**(4)EXPORT as .PDF**". The generated pdf file contains the same cover page and plots as the xlsx file, however, it does not include the PMF data worksheet – as converting this worksheet to pdf can fill more than 20 pages depending on the amount of data associated with the selected site. The filename of the pdf file will be automatically generated to be the same as the selected site.

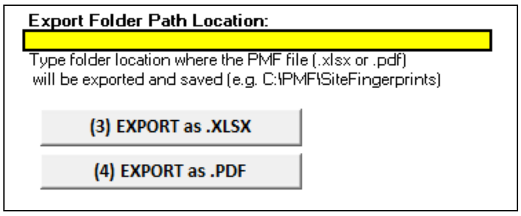

Figure 10 Section of Menu page related to xlsx or pdf file export

Cover Page

A cover page is automatically generated and included when you export the data as either an xlsx or pdf file (see **Figure 11**). This cover page provides the same SUMMARY INFORMATION shown on the Menu page (see **Figure 8**).

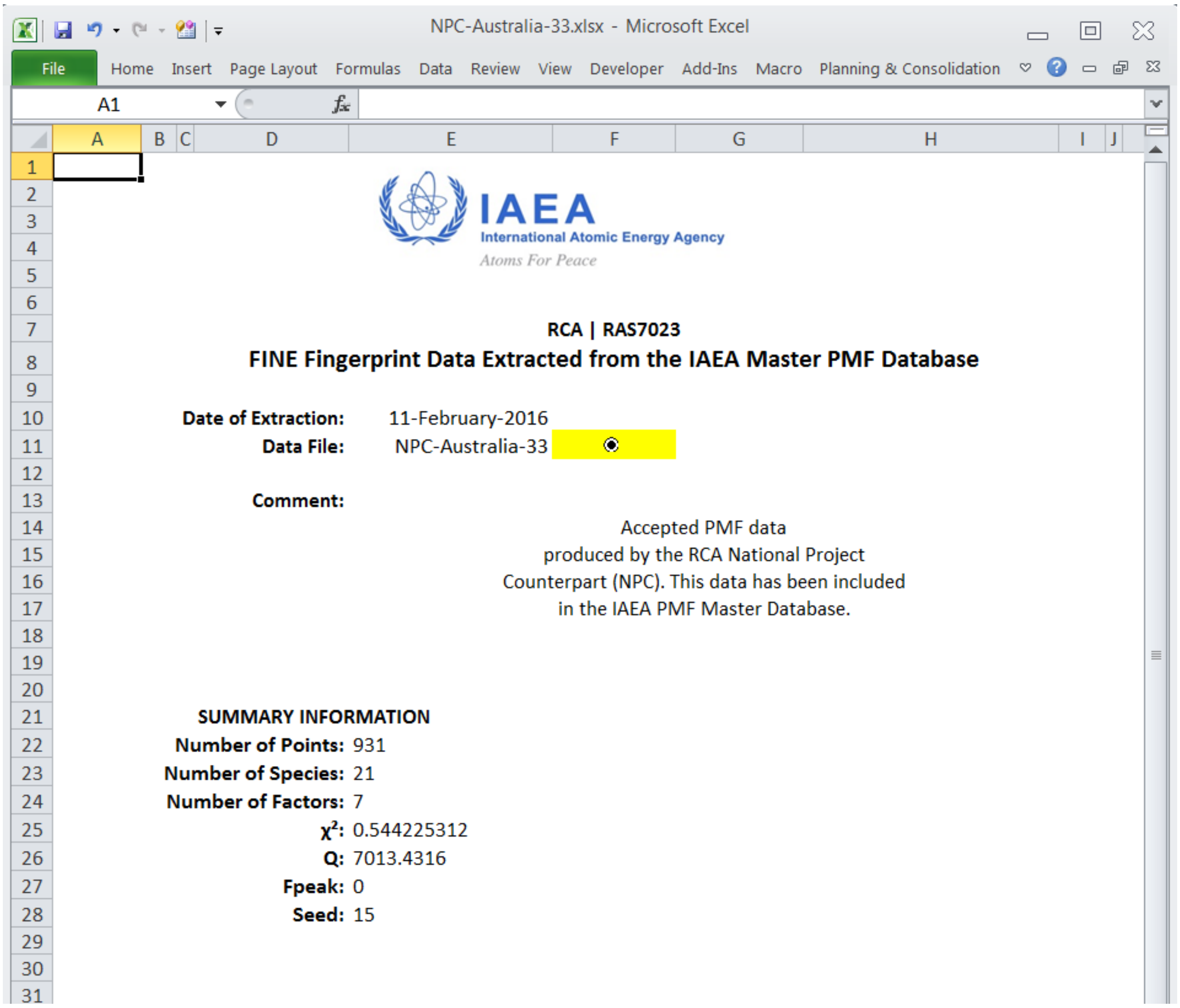

Figure 11 Example of the cover page worksheet included in exported xlsx or pdf files

3.3 Description of Extracted Worksheets

The following sections describe the various worksheets which are generated from the PMF data extraction process described in **Sections 3.2.1** and **3.2.2.**

3.3.1 Fingerint Plots

The PMF fingerprint plots are displayed on the FingerprintPlots worksheet (see **Figure 12**). Each fingerprint is comprised of the fractional ratios for each correlating element. The elemental ratios in each fingerprint have been normalised to have the maximum element with a value of 1. This clearly identifies the main driving element/s for a particular fingerprint and assist the data analyst in assigning possible fingerprint names. The Y-axis of each fingerprint is a 4-decade log plot which allows trace elements to also be easily identified. The error bars relate to 3 standard deviations calculated by the PMF analysis codes. The percentage value in brackets next to the title of each fingerprint denotes the percentage of that fingerprint to the total 'fitted' mass, not the total gravimertic mass.

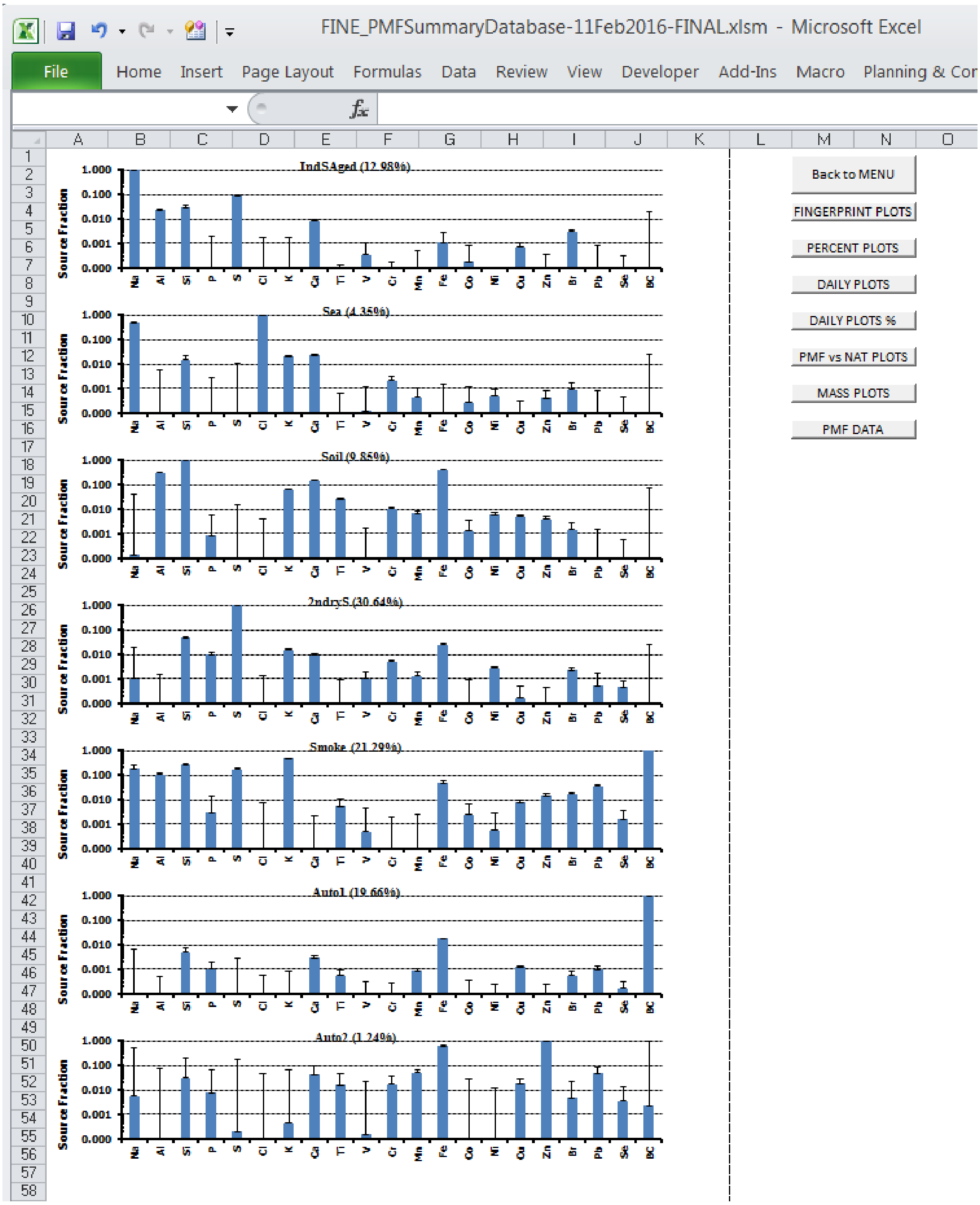

Figure 12 Example of a set of PMF fingerprints displayed on the FingerprintPlots worksheet. The worksheet navigation button panel is also seen on the right side of the image.

3.3.1.1 Fingerprint Abbreviations and Names

At this point it is worth re-emphasising the following statement from the earlier **Section 3.1**. The PMF analysis process does NOT automatically assign a receptor source fingerprint name to each resulting fingerprint. It only provides the contributing correlating elements which form the fingerprint. Each fingerprint is subsequently given a suitable name by the data analyst using local sampling site knowledge and experience in identifying the most likely source associated with the elemental fingerprint of each factor.

Also, when interpreting these PMF fingerprints it is important to be mindful of the distinction between *emission* source fingerprints and *receptor* source fingerprints, the latter related to this PMF database. Emission source fingerprints are the elements emitted directly from a specific process (for example, directly out of the exhaust pipe of a car). On the other hand, receptor source fingerprints relate to the elements measured at a location which is distant (often very far) from the original emission source. Clearly the receptor fingerprint would be significantly different to the original emission fingerprint. The assigned receptor fingerprint names in this database are therefore not definitive, but a best attempt by each member state to identify the dominant source/s in each mixed source receptor fingerprint.

The following table lists the main fingerprint naming abbreviations used. Many of the fingerprint names used in the database are also combinations of abbreviations, for example, IndFe would refer to an industrial source dominated by iron (Fe) or AutoRoad would refer to retrained road dust from automobiles.

Table 1 Key abbreviations used for PMF fingerprint naming and their associated descriptions

Fingerprint Abbreviation	Fingerprint Name	Key Elements and Description
Sea	Sea salt or Sea spray	Na or Cl as the main driving elements. Typically also has Mg, Br and S.
Soil	Windblown soil	Al, Si, Ca, Ti, Fe are the crustal matter elements typically associated with windblown soil. May also include Ba, Sr and Rb.
2ndryS	Secondary Sulfate	S as the main driving element, sometimes with traces of Na, Si, P, Ca, Ti, V, Fe, Ni, Zn, Se and Br. H and S are the dominant elements associated with ammonium sulfate.
Smoke	Biomass burning	K and BC, sometimes with Pb, as the main driving elements for smoke associated with biomass burning.
Ind	Industry	Dominant elements such as (but not limited to) Al, Ti, Cr, Ni, Co, Cu, Zn, Pb, S, As, Mo and Sb are often associated with a general industry source.
Auto	Vehicular related	S, Zn, Cl, Ca, Mn, Fe, Cr, V, Ni, Cu, Br, Pb. When a number of auto related fingerprints are identified, e.g. related to leaded, unleaded or diesel fuel and retrained road dust because of its relationship to automobiles emissions such as fuel combustion, brake and tyre wear; they are often numbered as Auto1, Auto2 or AutoRoad etc.
IndSAged	Industrial Sulphur Aged Seaspray	S, Na and BC are the dominant elements. Probably formed by chemical reactions of sea spray particles with sulfate particles from industry. The use of *Aged* in the abbreviation is due to the reduced Cl in the fingerprint associated with the ageing of sea spray.

3.3.2 Percentage Plots

The plots on the PercentPlots worksheet represent the percentage distribution of each of the elements across all identified fingerprints. For example, adding the Na percentage shown in each of the 7 fingerprints (see **Figure 13**) will account for 100% of the Na fitted mass. These plots are NOT source fingerprints and should not be used as such. They are used mainly to assess where the major contributions of each element reside in terms of fingerprints. Correct PMF fingerprint interpretation requires the use of both the fingerprints plots (**Figure 11**) and the percentage plots (**Figure 12**) in conjunction to best to identify meaningful receptor sources.

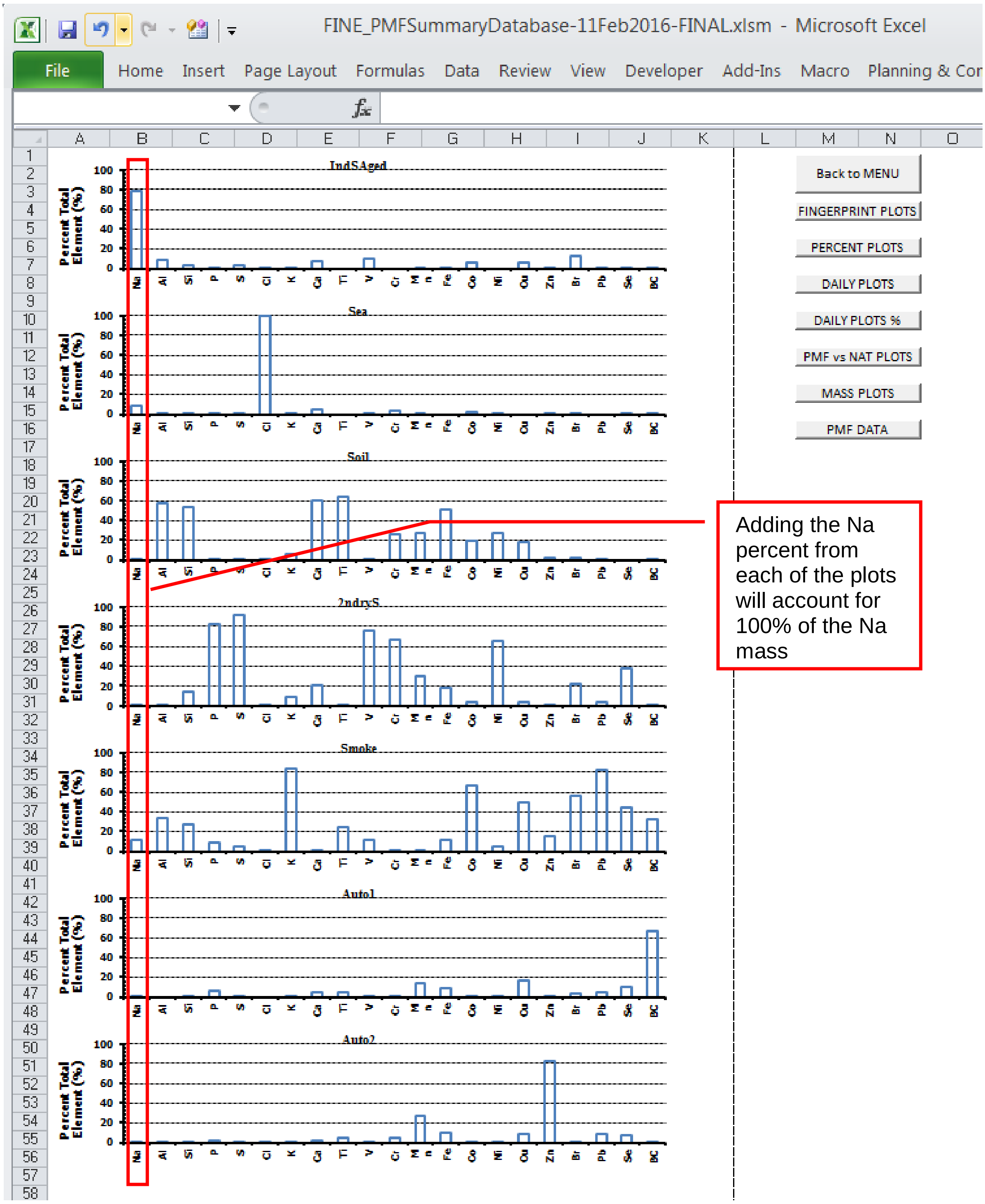

Figure 13 Example of a set of PMF percentage plots on the PercentPlots worksheet. The worksheet navigation button panel is also seen on the right side of the image.

3.3.3 Daily Plots

The plots on the DailyPlots worksheet (**Figure 14**) represent the daily contribution of each fingerprint in nanograms (ng/m³). The date on the x-axis has the format YYYYMMDD, for example 20120125 denotes Day, D: 25, Month, M: 01 and Year, Y: 2012.
These plots are useful in seeing daily, monthly and yearly trends for each identified fingerprint. Such trends may include: regular seasonal variations of particular receptor sources (e.g. summer-winter changes in receptor sources related to domestic heating), reduction in receptor sources as a result of the implementation of pollution reduction policies (e.g. cessation of leaded petrol), or natural events such as dust storms or bush fires. However, if any of these plots are driven by only one or two extreme events, the associated fingerprint is not likely to be representative of the entire dataset.
These plots are also useful for performing quality assurance of the PMF data by identifying any large unexplained and often unrealistic step-function changes in the time series of a receptor source fingerprint.

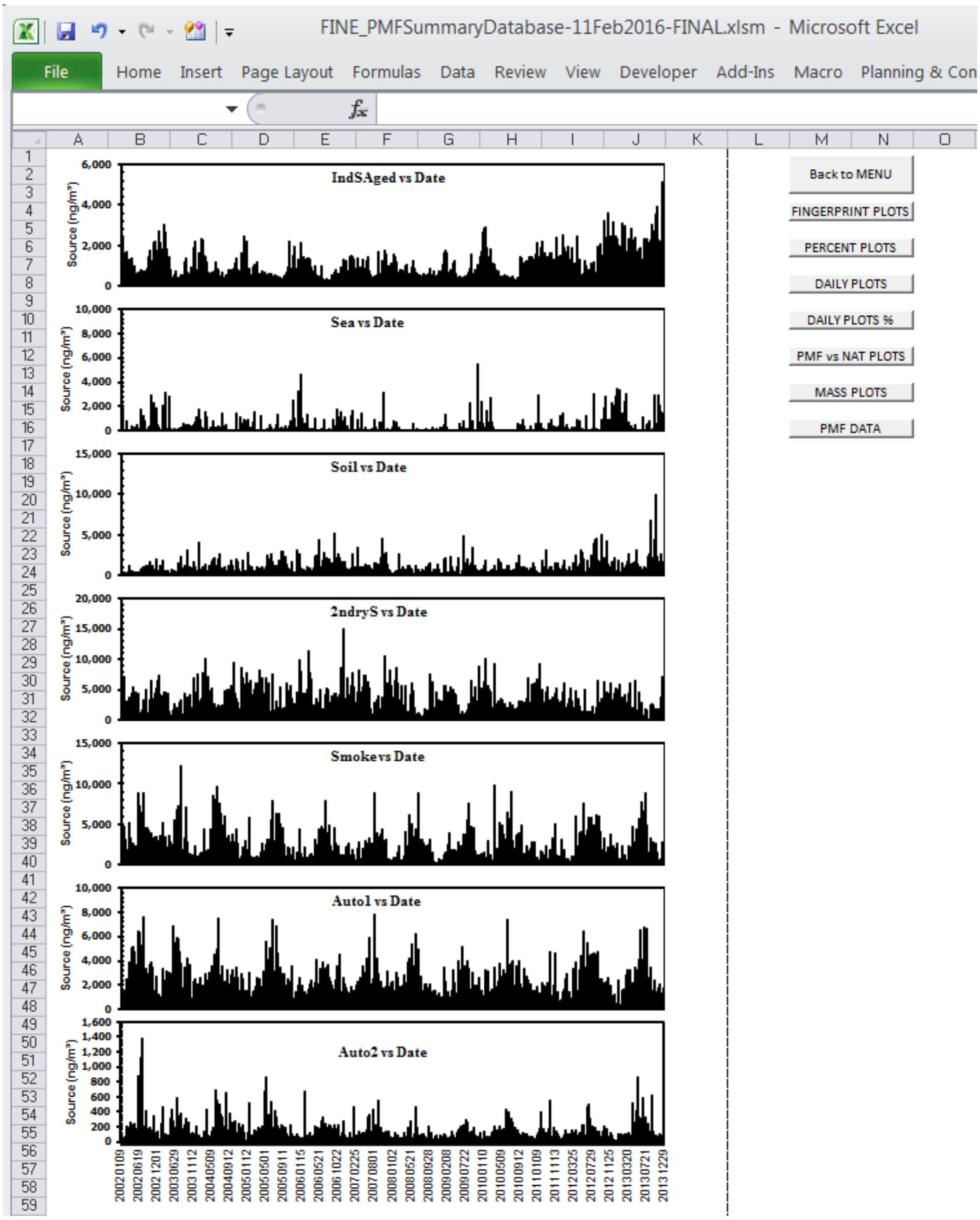

Figure 14 Example of plots on the DailyPlots worksheet showing each PMF fingerprints daily contribution in ng/m³. The date on the x-axis has the format YYYYMMDD, for example 20120125 denotes Day, D: 25, Month, M: 01 and Year, Y: 2012. The worksheet navigation button panel is also seen on the right side of the image.

3.3.4 Daily Percentage Plots

The plots on the DailyPlots% worksheet (**Figure 15**) are similar to the daily plots (**Section 3.3.3**) but instead of daily concentration in ng/m³, these plots represent the percentage (%) contribution of each identified receptor source to total pollution as a daily time series. The date on the x-axis has the format YYYYMMDD, for example 20120125 denotes Day, D: 25, Month, M: 01 and Year, Y: 2012.

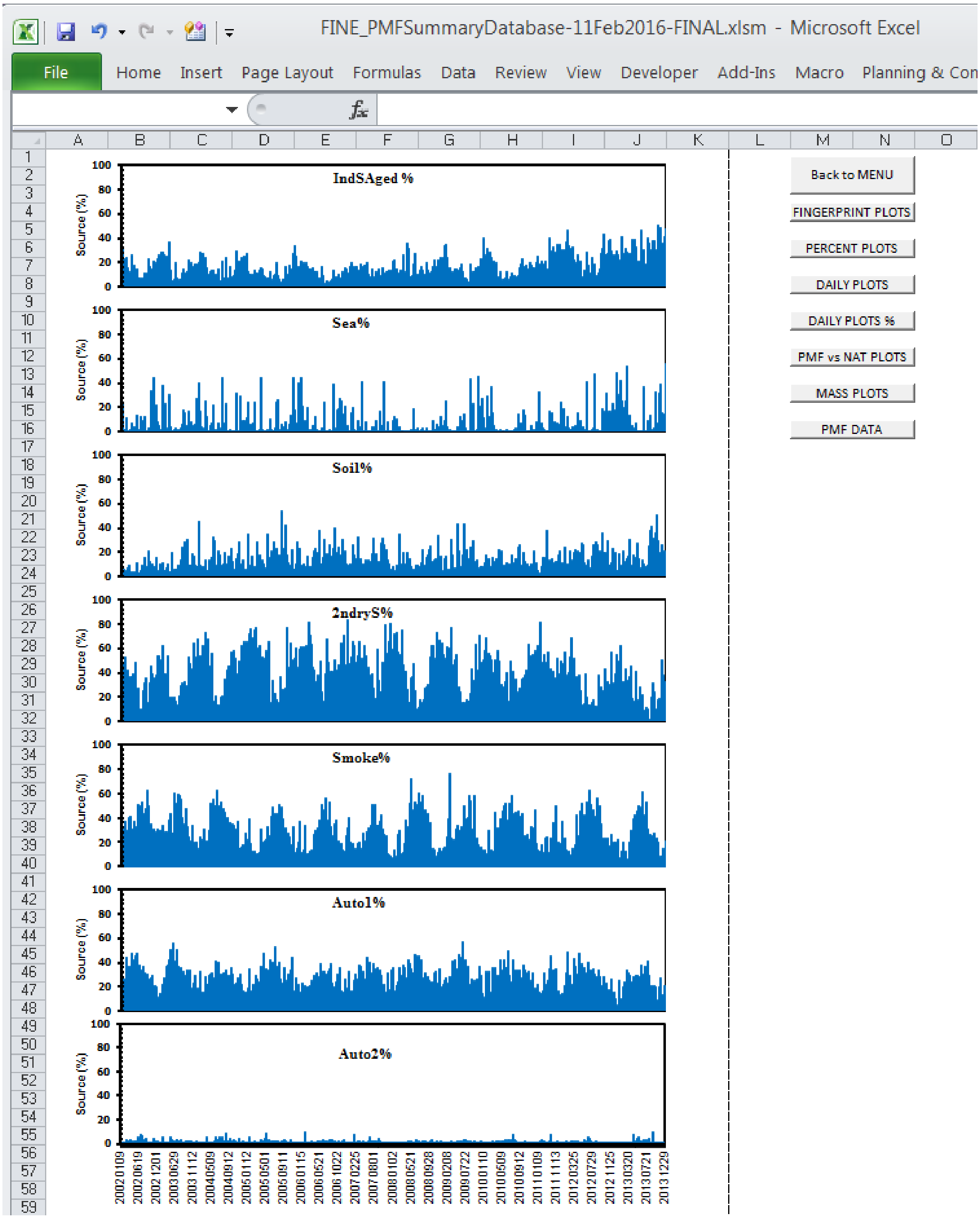

Figure 15 Example of plots on the DailyPlots% worksheet showing the each PMF fingerprints daily percentage (%) contribution. The date on the x-axis has the format YYYYMMDD, for example 20120125 denotes Day, D: 25, Month, M: 01 and Year, Y: 2012. The worksheet navigation button panel is also seen on the right side of the image.

3.3.5 Mass Plots

The MassPlots worksheet contains two mass related plots. The first plot compares the calculated PMF mass with the measured gravimetric mass, both in ng/m³. Ideally, both the linear fit and R^2 value should be close to 1. However, this linear fit can be skewed significantly by outlying points causing the fitted data to be representative of neither the majority of data nor the outlying point, but somewhere in-between. To avoid this, the data analyst generally tries to remove most of the outlying or extreme points outside of the "tramlines" represented by the dotted lines in the top plot of **Figure 16**). These tramlines represent a certain number of standard deviations (SD) from the fitted line, generally between 3 to 6 standard deviations. The tramline SD value which was applied in each site's PMF analysis is provided in the SUMMARY INFORMATION section (see **Figure 8**).

The second plot on the MassPlots worksheet is a time series comparison of both the PMF mass and gravimetric mass. It is used to check that the daily PMF fit obtained from statistical analysis matches the measured daily gravimetric mass.

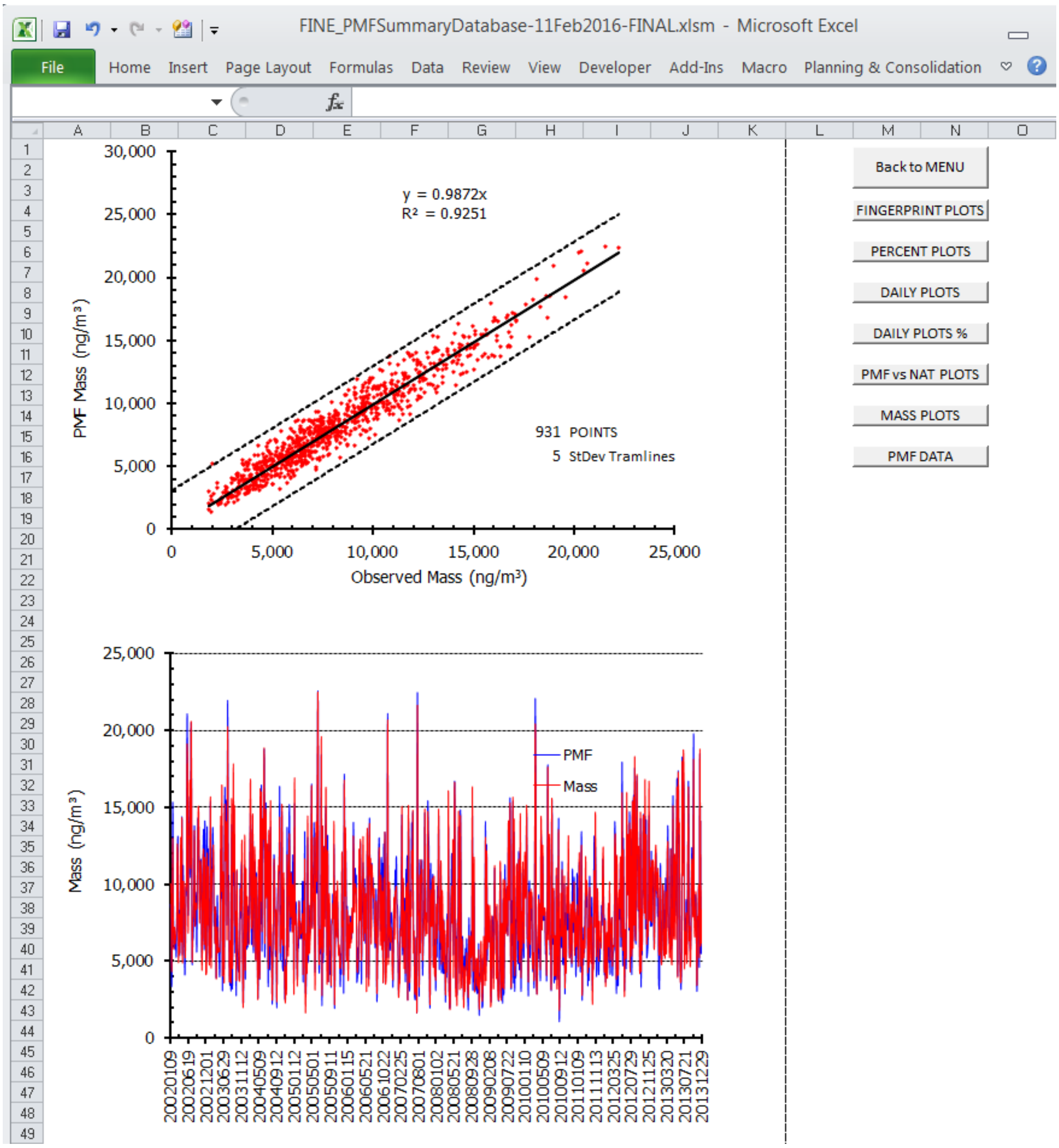

Figure 16 Example of plots on the MassPlots worksheet comparing PMF mass with gravimetric mass. The date on the x-axis of the lower plot has the format YYYYMMDD, for example 20120125 denotes Day, D: 25, Month, M: 01 and Year, Y: 2012. The worksheet navigation button panel is also seen on the right side of the image.

3.3.6 Elemental PMF versus Measured Plots

The plots on the PMFvsNATplots worksheet (**Figure 17**) represent the correlation of each elements PMF fitted value against its measured value obtained with the nuclear analytical technique (NAT). These plots provide a clear visualisation, element by element, of which elements have been fitted well by the PMF process. Ideally, the obtained gradient and R^2 for each element would be 1 if the PMF fit was perfect. This linear fit can be skewed significantly by outlier points resulting in a solution that is representative of neither the majority of data for that element nor the outlying point, but somewhere in-between. Therefore, during the PMF analysis process, the data analyst is able to systematically remove outliers from these plots in order to get closer to this ideal condition. However, for trace elements or elements with very large associated errors/MDLs, this is not often possible nor even advantageous as the PMF process will always be driven by elements with more accurate and precise measurements. These plots are also userful during the PMF analysis process in determining which elements can be removed from the PMF analysis as they have minimal impact on the final fits.

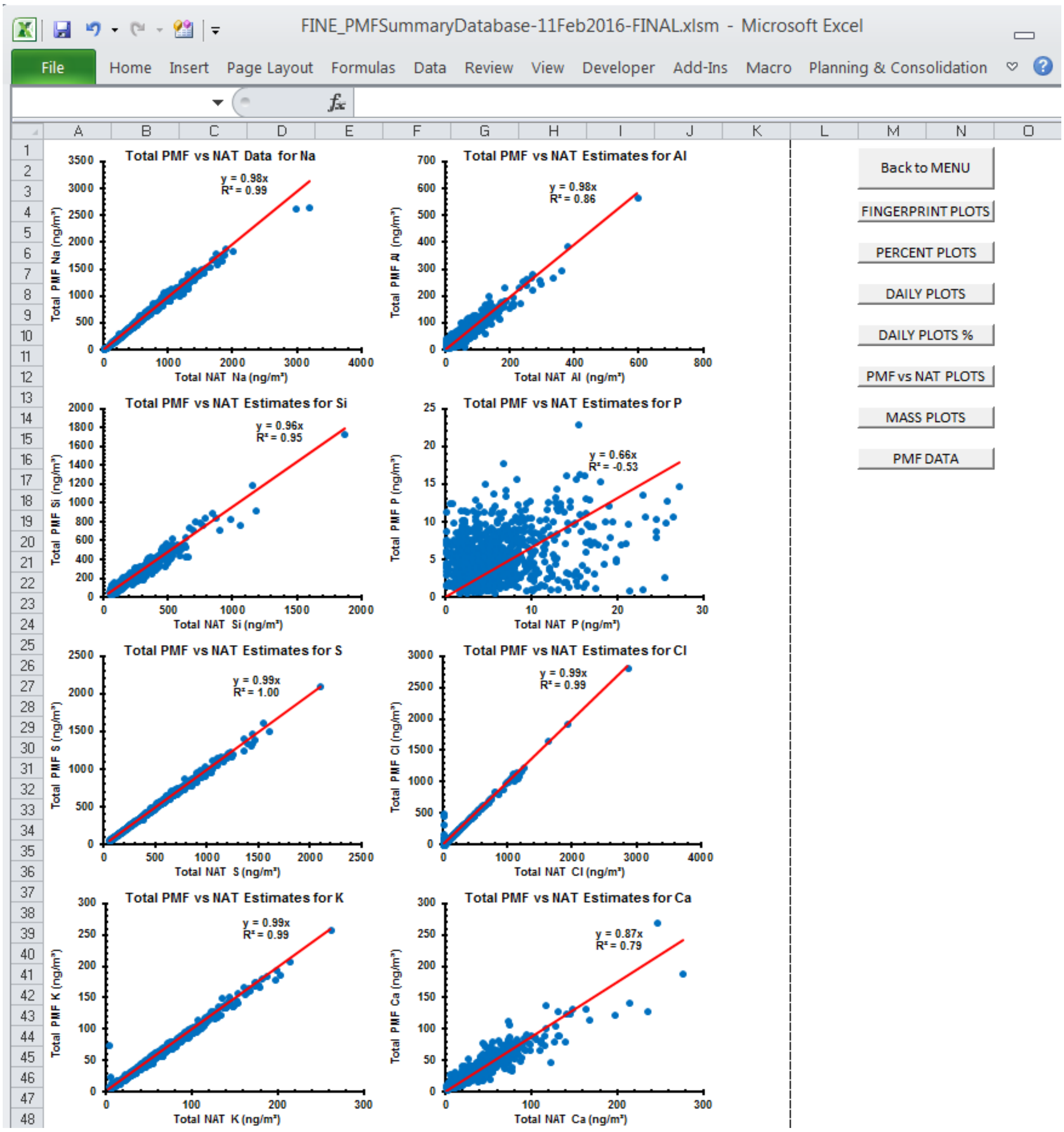

Figure 17 Example of plots on the PMFvsNATplots worksheet comparing PMF fitted concentration (ng/m³) against the nuclear analytical technique (NAT) measured concentration (ng/m³) for each element. The worksheet navigation button panel is also seen on the right side of the image.

3.3.7 PMF Master Data

The data contained on the worksheet with the selected sampling site name (e.g. NPC-Australia-33) represents the PMF Master Data related to that site and from which all of the previously described plots are generated. The following section of the present document will describe the various sections of data located on the PMF Master Data worksheet using the excel cell reference method of letter and column, e.g. “E10” refers to column E and row 10 (see **Figure 18**).

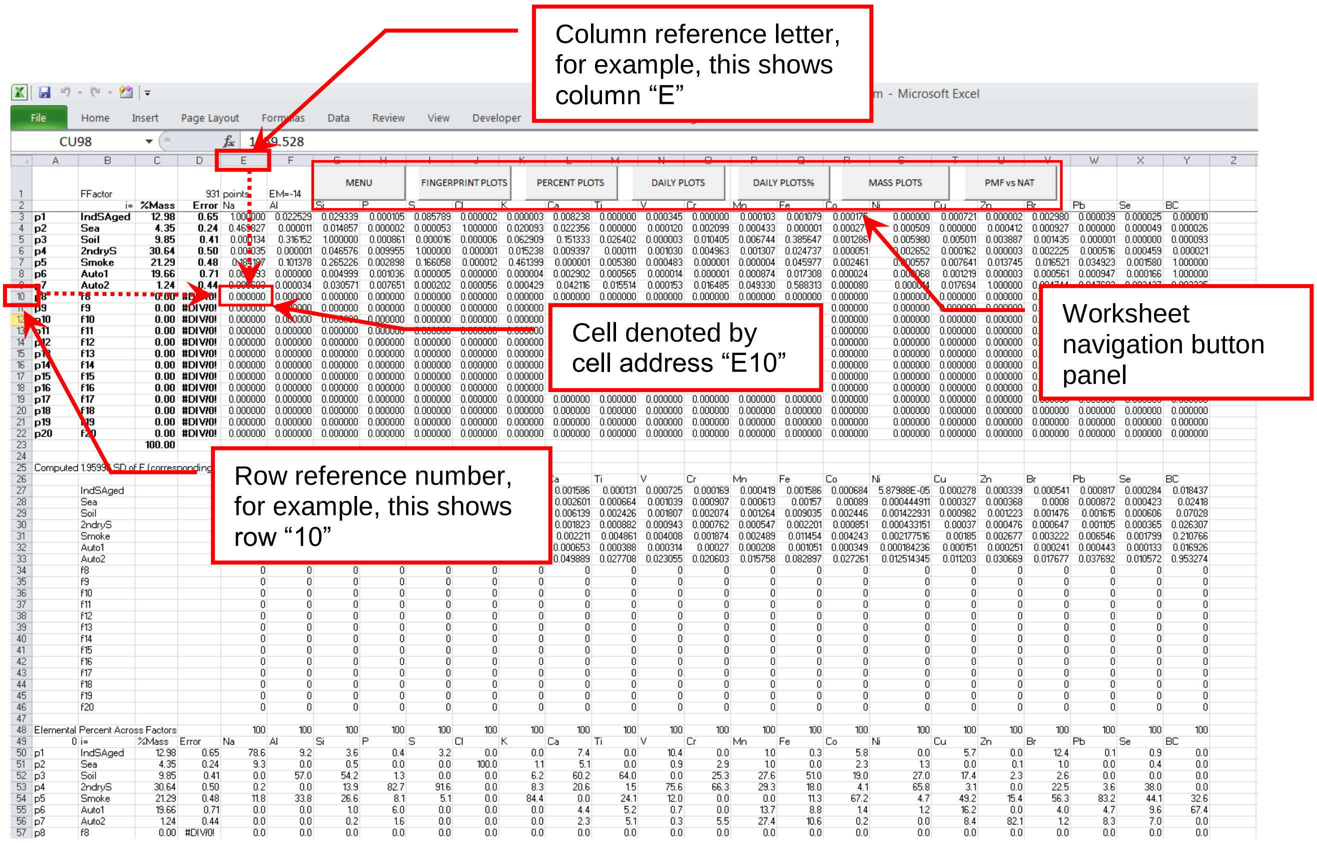

Figure 18 Example section of the PMF Data Master worksheet for site NPC-Australia-33 showing the cell reference method, for example cell E10, as show in the image. The worksheet navigation button panel is in a slightly different format/location to previous sheets and is seen along the top of the worksheet.

Important Note

When viewing the PMF Master Data worksheet for each member state, it should be noted that the PMF anlaysis program which generates this Master Data worksheet is capable of processing up to 20 different PMF fingerprints, but in reality we would rarely use that many fingerprints. Most sites to date are adequately accomodated by between 5-10 fingerprints. Therefore, you will notice many cells containing either zero or #DIV/0! values as these are related to unused factors of the available 20.

3.3.7.1 F-matrix

Rows 3 to 22 (across): Data related to fractional ratio contribution of each element in each fingerprint. It represents the F-matrix. In this data, the element with the largest contribution in each fingerprint has been normalised to 1. The fingerprint names are listed in cells B3 to B22, with their corresponding percentage mass contributions and associated error listed in cells C3 to C22 and D3 to D22, respectively. The elements included in the PMF analysis are listed in row 2 from column E and onwards across the worksheet (depending on how many elements were included in the analysis). This data is used to generate the fingerprint plots.

Cell D1: Number of points (i.e. days) included in the PMF analysis.

Rows 26 to 46 (across): Data related to calculated 95% confidence interval of the F-matrix data from column B and onwards across the worksheet depending on how many elements included in the analysis. This data is used to generate the error bars on each element in the figerprint plots.

Rows 48 to 69 (across): Data related to the percentage distribution of each element across all of the fingerprints from column A and onwards across the worksheet depending on how many elements included in the analysis. Therefore, the sum of each element's percentage contribution in each fingerprint, e.g. cells E50 to E69, results in a value of 100 percent as show in row 48 from columns E onwards (depending on how many elements were included in the analysis)

Rows 70 to 90 (across): Data related to manual Fkey pull-down strength used during the PMF analysis from column A and onwards across the worksheet depending on how many elements included in the analysis. Column B70 to B90 lists the fingerprint names related to that row of data. Columns E (for rows 70-90) onwards relate to the elements in each fingerprint (as listed in row 2). For example, cell E71 would refer to the Fkey value applied to the first element in the first fingerprint.
The optional Fkey option available during PMF analysis refers to the use of known external information to impose additional control on the rotation of the PMF analysis. For example, if specific elements in specific values are **known** to be zero, such as black carbon (BC) in a pure sea spray fingerprint, then assigning an Fkey value to that element can be used to force the PMF solution toward zero for BC values in that sea spray fingerprint. A range of Fkey pulldown strength may have been used between one, which has minimal pull-down strength, to nine which has the strongest Fkey pulldown strength. A value of zero, denotes no Fkey pull-down has been used.

Cell A96: Shows the year range of the dataset used in the PMF analysis

3.3.7.2 G-matrix

Cells A96 to AA97 (down): Data related to daily contribution of each fingerprint to total mass. This data represent the G-matrix. The names of the fingerprints are listed horizontally from cell F96 to Y96 with their data listed in the corresponding column below each name. Cells A97 to D97 (downward depending on the number of analysed days) relate to the corresponding Site, Day, Month and Year of each G-matrix data row. Column E97 and Z97 relate to the graviemetric mass concentration (Cmass) and fitted PMF mass concentration (FitCmass), respectively. Column AA97 relates to the datecode (YYYYMMDD) used in several of the plots in the worksheets described earlier.

Rows E92 and E92 (across): Data related to the average (mean) and standard deviation values, respectively, for the columns in "**Cells A96 to AA97 (down):**" described above.

Cell E94: Q-value obtained from analysis

Cell G94: Fpeak value used for analysis

Cell J94: Chi-squared value obtained from analysis

Cell M94: Seed value used for analysis

Row E95 to AA95 (across): Least squares linear regression coefficient values corresponding to each of the G-matrix columns from F98 to Y98 (down).

Rows AB96 AU96 (down): Daily percentage of each fingerprint to the total PMF fitted mass concentration (i.e. FitCmass). Summation of each row, e.g. AB98 to AU98 which represents the individual percentage contribution of each fingerprint for that day, should equal a value of 100%.

3.3.7.2 Tramlines

Columns AW97 to AZ97 (down): Data used to create the standard deviation tramlines on the PMF mass vs Observed Mass plot (see MassPlots worksheet, **Figure 16**).

Cell BA97: Standard deviation tolerance for the upper and lower tramlines

Cell BB97: Standard deviation of the values listed in the "Distances" column A97 (down)

3.3.7.3 Elemental PMF fits vs NAT data

Columns BD97 (across): Each column represents the daily total PMF fitted concentration (ng/m³) for each element listed in row BD97. This is followed by a blank column and then a column titled "Check".

After the "Check" column, the continuing columns across are the NAT concentration data (ng/m³) for each element. The "Check" column is an automatic programmatic check to ensure the correct NAT data has been imported and matched with the corresponding PMF data in this worksheet. This value is 1 if the NAT data has been imported correctly.

The above data is used to create the plots on the PMFvsNATplots worksheet (see **Figure 17**).

4. Additional Menu Functions

4.1 IAEA RCA website link

NB: this function requires internet connection

Clicking the IAEA logo on the Menu worksheet will open your default internet browser to the IAEA RCA website (https://www.iaea.org/technicalcooperation/Regions/Asia-and-the-Pacific/RCA/).

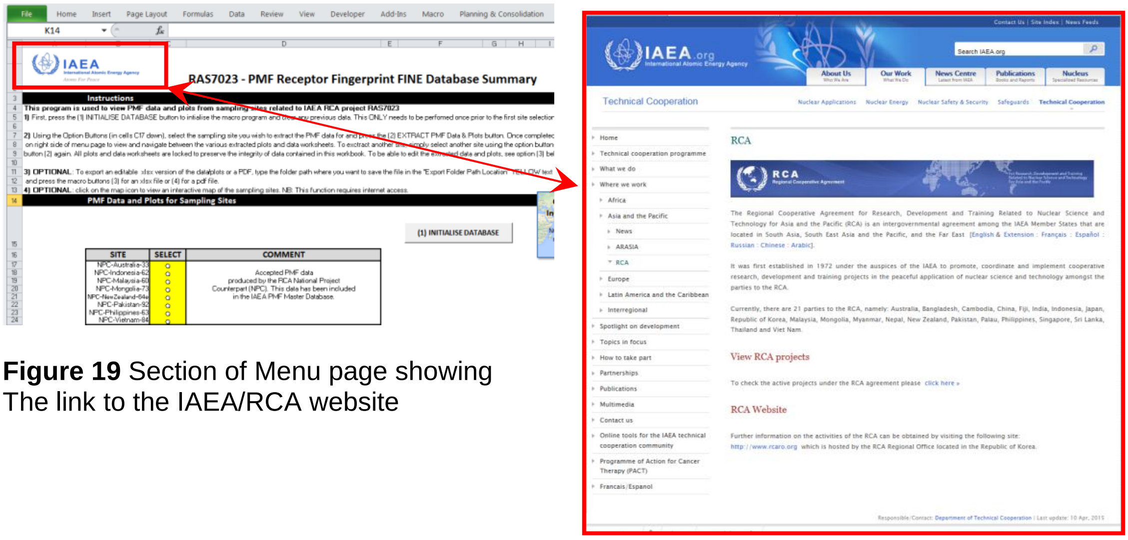

Figure 19 Section of Menu page showing The link to the IAEA/RCA website

4.2 Interactive Site Map

NB: this function requires internet connection and the "SamplingSiteMap.html" file must be located in the same folder as the IAEA PMF Master Database file.

Clicking the interactive map button on the Menu worksheet accesses generates a map of the sampling sites which it displays in a new internet browser window using Google Maps. The "Map" and "Satellite" button in the top left corner of this map window can be used to alternate between these views. Clicking on any of the red site markers on the map will jump to a zoomed-in image of that particular site. Clicking the red site marker again will jump back to a zoomed-out image of the map. At any stage, you can also use the plus (+) and minus (-) buttons in the bottom right corner of the browser window to manually zoom in and out of a site and its local and regional surroundings.

NB: If this function fails to open correctly from within the database, please try opening the SamplingSiteMap.html file directly using an internet browser other than Internet Explorer (e.g. Chrome, Firefox or Safari).

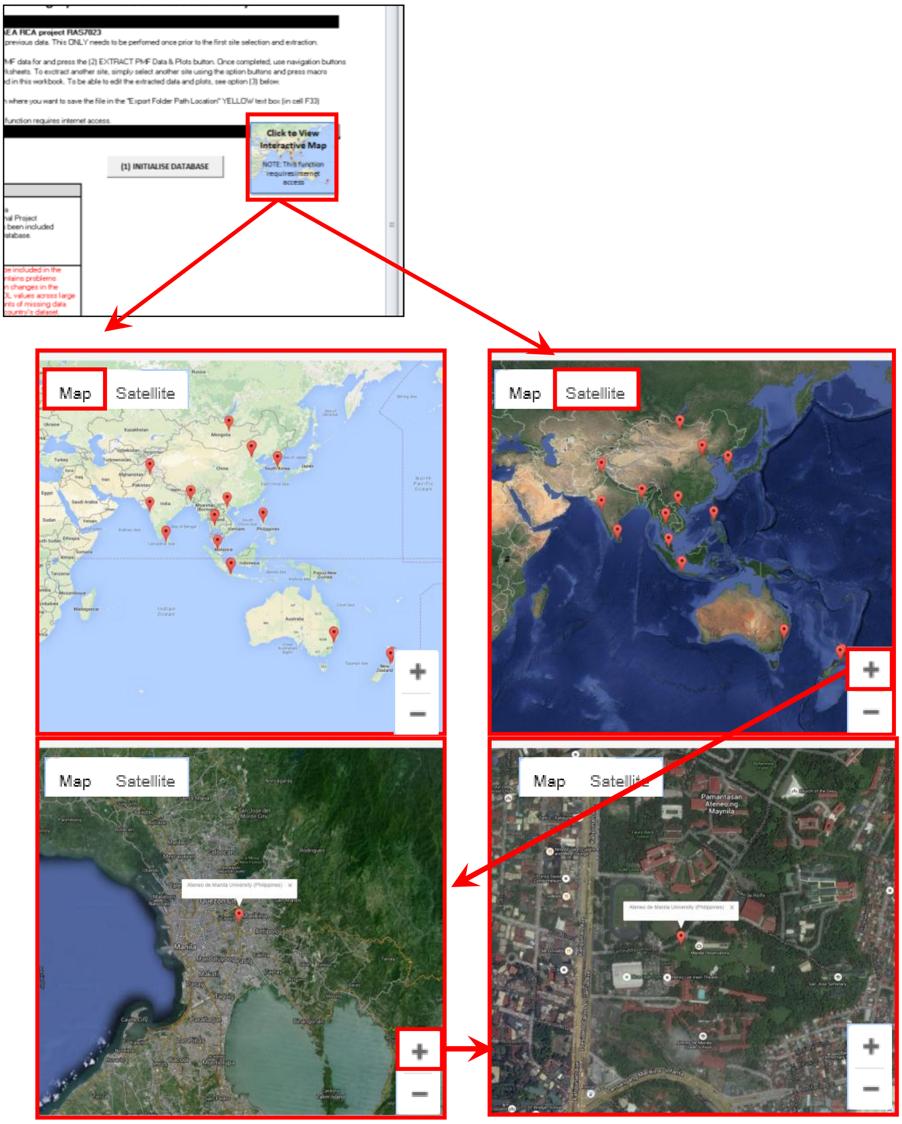

Figure 20 Section of Menu page showing link to the interactive map. The lower figures show location of map options to switch between Map view and Satellite view, as well as the plus (+) and minus (-) zoom functions.

5. Summary

- Compilation of the IAEA PMF Master Database for both coarse and fine particulate matter has been completed as of 31 January 2016.
- 11 of the 14 member state NPC's have successfully performed PMF analysis on the IAEA A-PAD database to generate a set of average PMF fingerprint solutions for coarse particulate matter receptor sources at their site spanning up to 10 years.
- Of the 11 coarse PMF data solutions, 7 have been accepted into the final PMF Master Database.
- All 14 member state NPC's have successfully performed PMF analysis on the IAEA A-PAD database to generate a set of average PMF fingerprint solutions for fine particulate matter receptor sources at their site.
- Of the 14 fine PMF data solutions, 8 have been accepted into the final PMF Master Database.
- Macros have been written for both the coarse and fine PMF database to facilitate extraction, plotting and exporting of the PMF data solutions for each member state.

These PMF databases represent unique particulate matter datasets. They provide both coarse and fine PMF receptor source fingerprints using nuclear multi-elemental analytical data, spanning up to 10 years and 14 countries across the greater Asia-Pacific region. The original A-PAD elemental data and subsequent PMF analysis has been performed in many cases by the national project counterpart (NPC) from each member state providing significant and specific expertise in relation to NAT data contained in the A-PAD, sampling site location, emission sources, localised conditions and PMF fingerprint interpretation and naming. It is clear from the PMF analysis performed by the NPC's that the quality of the starting database, in this case the IAEA A-PAD, plays a significant role in the quality of the subsequent PMF analysis. Some examples include, for example:

- Changing the NAT method utilised from PIXE to XRF during the sampling/analysis campaign can manifest itself as a significant step-function change in one or more PMF fingerprint time series as a results of adding/losing elements or changes in analytical sensitivity.
- Missing or inconsistent data (concentrations or associated errors and MDL's) in the database can also have a significant impact on the quality of the PMF solution.

Data identified with these types of issues have not been included in the final PMF Master database, but still provided in the database for completeness along with appropriate warning comments.
This database has the potential to be used to look at source trends across the Asia-Pacific regions, including the possibility of long-range transport across neighbouring member states. We believe it will be a valuable resource for researchers and other environmental stakeholders for many years to come.

Table 2 A summary table of the COARSE PMF results accepted for inclusion in the master PMF database

COARSE

AUSTRALIA

PMF Mass (ng/m^3)	
Average	**Std. Dev.**
12906	6733

Fingerprint Name	% PMF Mass	Error
Sea	35.61	0.47
IndSAged	10.21	0.97
Soil	38.86	0.71
Auto	15.33	0.72

INDONESIA

PMF Mass (ng/m³)	
Average	**Std. Dev.**
17235	8736

Fingerprint Name	% PMF Mass	Error
Soil	40.87	1.42
SeaShipping	5.7	0.84
Smoke	13.39	0.92
IndCa	16.28	1.29
Auto	11.96	1.35
2ndrySVolcano	11.8	1.16

MALAYSIA

PMF Mass (ng/m³)	
Average	**Std. Dev.**
19834	6474

Fingerprint Name	% PMF Mass	Error
Soil	10.5	2.73
IndCl	4.65	1.44
SoilConstruction	21.41	1.98
Auto1	43.89	2.78
Auto2	19.55	3.1

MONGOLIA

PMF Mass (ng/m³)	
Average	**Std. Dev.**
130592	79563

Fingerprint Name	% PMF Mass	Error
Dust	16.72	5.04
Soil	52	3.35
2ndryS	16.43	3.52
IndCoal	13.34	3.62
Auto	1.5	3.37

New Zealand

PMF Mass (ng/m³)	
Average	**Std. Dev.**
7134	3497

Fingerprint Name	% PMF Mass	Error
Seaspray	56.1	1.95
Soil	15.19	1.35
Auto	13.63	2.45
Smoke	15.07	1.45

PHILIPPINES		
PMF Mass (ng/m³)		
Average	Std. Dev.	
24511	11185	

Fingerprint Name	% PMF Mass	Error
Seaspray	7.45	0.43
Soil	41.94	0.56
Ind1	14.42	0.72
Auto	31.16	0.78
IndZn	5.03	0.43

VIETNAM		
PMF Mass (ng/m³)		
Average	Std. Dev.	
38560	23265	

Fingerprint Name	% PMF Mass	Error
Sea	4.82	1.7
IndMetal	12.88	2.69
Soil	36.53	4.55
AutoOil	24.71	4.35
2ndryS	17.72	2.31
IndZn	3.34	1.85

Table 3 A summary table of the FINE PMF results accepted for inclusion in the master PMF database

FINE

AUSTRALIA		
PMF Mass (ng/m³)		
Average	Std. Dev.	
8181	3710	

Fingerprint Name	% PMF Mass	Error
IndSAged	12.98	0.65
Sea	4.35	0.24
Soil	9.85	0.41
2ndryS	30.64	0.5
Smoke	21.29	0.48
Auto1	19.66	0.71
Auto2	1.24	0.44

INDONESIA		
PMF Mass (ng/m³)		
Average	Std. Dev.	
17603	6983	

Fingerprint Name	% PMF Mass	Error
2ndryS	41.57	1.72
Soil	4.87	1.46
Smoke	13.4	1.28
Auto1	14.95	1.53
IndCa	4.21	1.5
Auto2	18.72	1.5
IndZn	2.29	1.04

MALAYSIA		
PMF Mass (ng/m³)		
Average	Std. Dev.	
22303	9362	

Fingerprint Name	% PMF Mass	Error
Soil	11.44	1.18
Smoke	12.08	1.57
2ndryS	26.75	2.09
Ind metal	4.58	0.9
Auto dust	1.32	2.38
Auto	43.84	2.78

MONGOLIA		
PMF Mass (ng/m³)		
Average	Std. Dev.	
69400	42216	

Fingerprint Name	% PMF Mass	Error
Soil (Natural)	27.03	4.84
2ndryS	20.83	3.05
Smoke (Coal Burning)	14.22	4.1
Soil (Dust)	18.94	4.15
Auto	12.38	6.55
Ind (Incinerator)	6.6	1.57

New Zealand		
PMF Mass (ng/m³)		
Average	Std. Dev.	
6044	3953	

Fingerprint Name	% PMF Mass	Error
Seaspray	25.79	1.62

Smoke	32.62	0.73
Soil	5.78	2.11
2ndryS	19.05	1.89
AutoBC	16.77	2.9

PAKISTAN

PMF Mass (ng/m³)	
Average	**Std. Dev.**
9835	6937

Fingerprint Name	% PMF Mass	Error
Soil	17.36	1.52
IndCr	7.85	1.45
IndCl	4.07	0.45
2ndryS	13.54	1.53
IndConstruct	10.83	1.66
Smoke	39.53	1.51
Auto	6.82	0.79

PHILIPPINES

PMF Mass (ng/m³)	
Average	**Std. Dev.**
33697	12010

Fingerprint Name	% PMF Mass	Error
Seaspray	10.8	0.56
2ndryS	19.44	0.51
Smoke	18.82	0.52
Ind1	3.46	0.41
Auto	45.27	0.72
Ind2	2.21	0.35

VIETNAM

PMF Mass (ng/m³)	
Average	**Std. Dev.**
32449	12551

Fingerprint Name	% PMF Mass	Error
Soil	10.86	2.73
2ndryS	28.88	2.01
IndMetal	3.89	3.21
Smoke	7.29	2.3
AutoOil	29.78	2.63
IndCoal	12.16	1.83
AutoRoad	4.56	1.2
IndClZn	2.58	0.9

6. Acknowledgements

The authors 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 and the initial extensive involvement of Dr Rainer Siegele in compiling the A-PAD dataset. This work has been performed under contract from the IAEA.

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Appendix 1

Sampling Site Descriptions

Location and site description for the 14 RCA sampling sites involved in 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.

Member state	Site	Type	Longitude	Latitude	Techniques	Mass Atten. Coeff. (m^2/g)	Site Description	Known emission 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	Soil, seasalt, motor vehicles,

							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 above sea level, close to the Boscha observatory	biomass burning and road dust
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	Urban	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	Suspended soil, dust and automobiles sources. Sources of Sea salt are

							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 small residential colony and a fleet of about 500 vehicles including buses, cars, wagons, trucks and motor cycles.	probably long range.
	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	79.8506	6.9337	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	Soil,

							commercial stores urban housing, railway line and Colombo harbour within 2 km. Main bus stand is situated within 3 km to north.	Vehicular emissions, Secondary sulphate, seas spray.
Thailand	Pathumwan, Bangkok	Urban	100.49 E	13.75	INAA	5.7	Capital city, Curbside at downtown 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.	Autos, Soil, 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

Project Related Publications

The following is only a partial list (alphabetically by member state) of refereed journal publications related to the databases and provided by each member state. It contains 134 journal publications between the years 1997 and 2015.

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.

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