Managing naturally occurring radioactive material (NORM) in mining and mineral processing — guideline

NORM-3.5

Monitoring NORM — measurement of particle size



Government of **Western Australia** Department of **Mines and Petroleum** Resources Safety



Reference

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1. General information

1.1. Purpose

To provide guidance on the measurement of the particle size of radioactive dust that may be encountered in exploration, mining and mineral processing operations.

1.2. Scope

This guideline applies to all exploration, mining and mineral processing operations in Western Australia that use or handle naturally occurring radioactive material (NORM) and come within the scope of Part 16 of the Mines Safety and Inspection Regulations 1995 [1].

1.3. Definitions

Aerodynamic Diameter The Aerodynamic Diameter of a particle is defined as the diameter of a sphere of unit density (1 g/cm^3) that has the same aerodynamic behaviour (e.g. settling velocity) as the particle itself. Particles of the same physical diameter but different densities will have different terminal velocities and, therefore, different aerodynamic diameters.

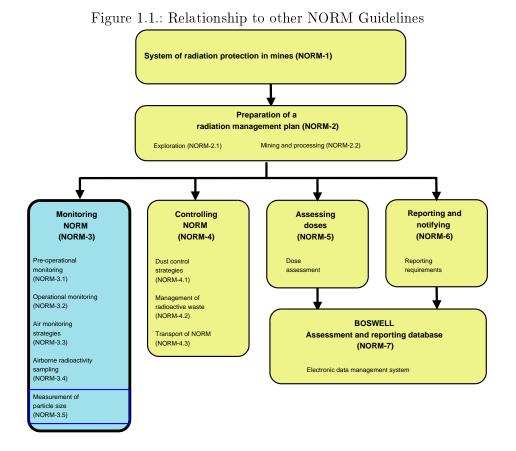
Equivalent Aerodynamic Diameter (EAD) Two particles of different densities are said to have Equivalent Aerodynamic Diameter (EAD) if their densities and diameters are such that their terminal settling velocities are equal.

Activity Median Aerodynamic Diameter (AMAD) Activity Median Aerodynamic Diameter (AMAD) is the EAD value of radioactive dust such that 50% of the activity in the dust is associated with smaller particles. The accurate determination of this value is critical in the process of the assessment of internal exposure of employees (NORM-5 Dose assessment).

Mass Median Aerodynamic Diameter (MMAD) Similarly, the Mass Median Aerodynamic Diameter (MMAD) of airborne dust is the EAD value such that 50% of the mass of the dust is associated with smaller particles.

1.4. Relationship to other NORM guidelines

The flowchart in Figure 1.1 shows the arrangement of the Radiation Safety Guidelines.



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2. Guidance

2.1. Summary

The biological effects of inhaled dust depend on the size of dust particles and it is, therefore, necessary to determine this value and the associated radioactivity in the workplace atmosphere. Basically, the smaller particles of radioactive dust are easier inhaled and their depth of penetration in lungs is higher than for the larger particles. Figure 2.1 on the next page demonstrates how the size of dust particles affects their deposition in the human respiratory system.

Particles encountered in practice are rarely regular in shape, and size parameters can be assigned to them in different ways. There is a wide variety of instruments for the determination of the particle size, based on different physical principles. For example, a cascade impactor is based on particle inertia, a laser aerosol spectrometer is based on light scattering, and an electron microscope uses a projected area image. It is, therefore, important to specify the method of measurement whenever particle size data is discussed.

Appendix A in NORM -5 describes the ICRP 66 [5] lung model for the respiratory tract regions. Deposition of dust particles is governed by either the activity median aerodynamic diameter (AMAD) or the mass median aerodynamic diameter (MMAD) of the inhaled aerosol. The percentage of activity or mass of an aerosol which is deposited in the different regions is given as a function of the AMAD of the aerosol distribution.

2.2. The monitoring method

AMAD is commonly determined using an inertial separation technique, which provides a direct determination of aerodynamic diameter. The inertial separation device separates the aerosol into particle size groups with a known range of aerodynamic diameter. The activity associated with each of the particle groups is easily determined by either radiological or chemical analysis, and statistical handling of data yields the activity median aerodynamic diameter (AMAD).

A personal lightweight cascade impactor is the preferred instrument for determining AMAD. The Marple cascade impactor shown in Figure 2.2 on the following page is an example of this type of equipment. Cascade impactor collection is based on the relative inertial properties of particles in an air stream changing its flow direction from perpendicular to parallel on the impaction surface. Particles with sufficient inertia due to their size and density will not follow the direction of airflow, but will impact upon and be retained by the collector surface. This principle is illustrated in a drawing in Figure 2.3 on page 5.

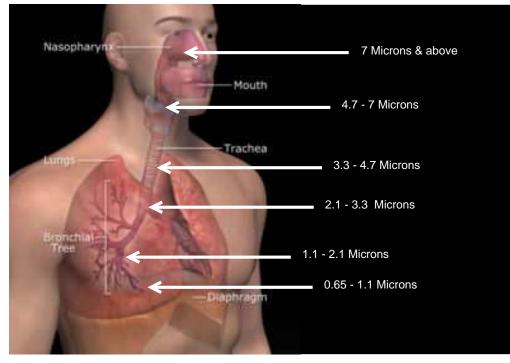


Figure 2.1.: Dust removal by the human respiratory system [3]

Figure 2.2.: The assembled Marple cascade impactor



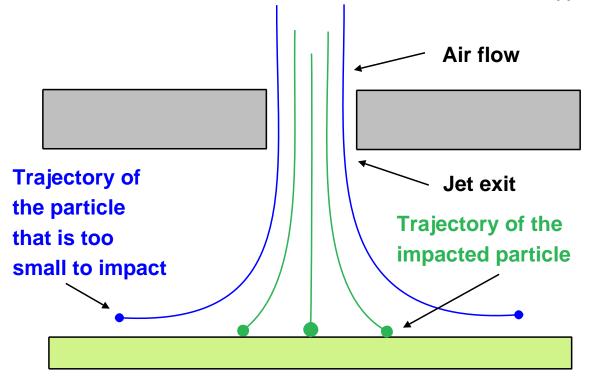
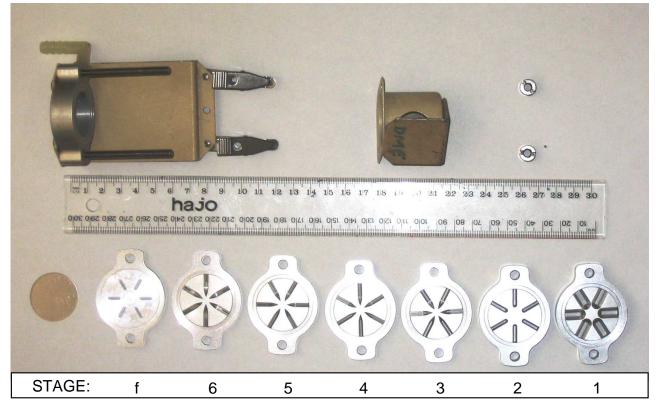


Figure 2.3.: An illustration of the Marple cascade impactor operating principle [3].

Figure 2.4.: The several stages that make up the Marple cascade impactor



As several impaction stages of decreasing jet widths (therefore \Rightarrow higher flow rates) are arranged in series, successive stages collect progressively smaller particles. A disassembled Marple cascade impactor showing the several impaction stages is shown in Figure 2.4 on the preceding page.

A mesh to hold the fine filter to collect all the particles passing the impaction stages usually follows the last stage which can also be seen in Figure 2.4. Many different models of personal impactor are currently available and a consultation with DMP is necessary prior to acquiring the equipment to ensure that it will be suitable for the industry sector in which it will be used. For example, several models were designed exclusively for the measurement of wood dust and, whilst marginally acceptable for phosphate and bauxite industry, may not be suitable in other industry sectors.

The main sources of error in the use of a personal impactor are wall loss, particle bounce and the incorrect choice of a collection surface. The errors due to the wall loss can be minimised by choosing an appropriate impactor model. To ensure that the possibility of other errors is also minimised the following precautions should be taken:

- 1. The use of bare metal, glass or other hard surface as an impaction surface should be avoided when sampling solid aerosols.
- 2. The use of glass fibre substrates may introduce significant errors, but for an 'approximate' measure of the size distribution AMAD they may be useful.
- 3. Oils and solvent/grease coatings used on collection substrates should be of suitable stability to prevent the coating 'flowing' under the jet, especially for the lower stages. If the coating flows under the jet, the exposed substrate surface will accommodate bounce and blow-off and consequently give incorrect results. Silicone grease or Vaseline in a suitable solvent are typically used.
- 4. Care should be exercised so that the loading capacity of the impactor is not exceeded. This can be accomplished by limiting the sampling time based on the expected dust concentration. Over-sampling manifests itself as trails of particles leading from the sample deposits towards the edge of the plate, rather than as well defined, discrete piles of particulates.
- 5. The incorporation of a deflector plate (inlet cowl) above the impactor inlet to prevent direct fall of large particles into the impactor (refer to Figures 2.2 on page 4 and 2.3 on the preceding page.

The *default* size of AMAD is 5 microns (μ m) and in the absence of sufficient data the dose conversion factor associated with this particle value is used in dose assessments (Guideline NORM–5 Dose assessment). If, however, the AMAD of dust particles in a particular operation is significantly different from this value, a special particle size characterisation program can be used to obtain data for the quantification of AMAD. The typical requirements of the annual program:

- 1. At least two valid personal impactor samples are required for each month (several confirmatory positional samples are also recommended).
- 2. At least five personal impactor samples per year are required for each of the 'major' work categories.
- 3. A final report on the AMAD monitoring program should be presented to DMP as soon as possible after the first of April each year and before the Annual Occupational Radiation Monitoring Report. The data is assessed and, if warranted, an alternative dose conversion factor is provided to the company (please refer to guideline NORM-6 Reporting requirements for additional information).

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2.3. Determining the AMAD

Once the dust particles have been sized by the impactor, an analysis of the activity associated with each particle size (aerodynamic diameter) fraction is required to determine the AMAD. Recommended analysis techniques include gross alpha counting and, in rare cases, x-ray fluorescence (XRF) spectrometry.

For glass fibre filter papers and oil-coated substrates of diameters less than 47 mm, the substrates can be analysed directly for alpha activity, similarly to the standard dust samples. However, practical limitations of this method include the possibility of alpha self-absorption due to large particles on top stage and, also, deposit build-up effects. Some impactors deposit the aerosol onto very small areas (usually rectangular or circular) and, given the small range of alpha particles, significant build-up can influence the registered activity.

Where the collection substrates are too large for the direct assay, or when too little sample is collected, other analysis techniques are required. With samples collected with high volume samplers and on large filter papers XRF method can be used. This involves grinding the filters with boric acid, pressing the mixture into a briquette and analysing by XRF for the element sought (thorium and/or uranium). For filters with a smaller dust loading, XRF of a fusion disc sample will increase the sensitivity.

Large samples can be removed from oil or solvent/grease coated substrates by appropriate chemical treatment (e.g. solvent washing). The collected material may then be re-deposited onto small filter papers for alpha counting or assayed using XRF, gamma spectroscopy, liquid scintillation counting or another appropriate technique. Such sample preparation will, however, increase the determination time and complicate the activity measurement.

Practical considerations, involving the choice of equipment include:

- 1. The collection media should preferably be in such a form that it can be placed directly into an alpha counter or be amenable to simple sample preparation.
- 2. The deposition pattern on collection substrates should be such that significant deposit buildups do not occur to minimise alpha self-absorption effects.
- 3. The flow-rate through the impactor should be adjusted so that a range of particle size cutoffs can be collected to suit the dust distributions encountered in a particular operation. In general, flow rates between 2 and 5 litres per minute may be utilised in sampling.
- 4. The device must have a dust loading capability of greater than 0.5 mg per stage so that the substrates can be analysed directly by gross alpha counting.
- 5. The impactor should have the optimum number of collection stages (typically between 5 and 7 stages), which would allow size separation to be made with adequate resolution.

An example of the procedure for setting up of a seven-stage personal impactor and associated issues is presented in Appendix A on page 25.

3. Data processing

3.1. Manual data processing

3.1.1. MMAD and associated calculations

For the calculation of the total dust concentration three parameters are required:

- 1. 'pre-weight' of the each impactor stage i;
- 2. 'post-weight' of the each impactor stage i; and
- 3. sampling time.

Since the flow rate of the constant flow sampler is known (usually 2 litres per minute), the *volume* (V) of the sample is calculated as follows:

$$V(m^3) = \frac{T_{SAMP} \times FR}{1000}$$

where:

 T_{SAMP} = sampling time in minutes; and

FR = sampler flow rate in litres per minute. The *total weight of each stage* (TWi) is calculated as follows:

 $TWi(mg) = WTi_{POST} - WTi_{PRE}$

where:

 WTi_{POST} = weight of the stage i after sampling; and WTi_{PRE} = weight of the stage i before sampling.

a) The total weight of the sample (TWS) is calculated as follows:

$$TWS = \sum_{i=1}^{7} (WTi_{POST} - WTi_{PRE})$$
$$= \sum_{i=1}^{7} TWi, i = 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, 6^{th}, 7^{th}(f - final)stages$$

b) The total dust concentration (Dc) of the sample is calculated as follows:

$$Dc(mg/m^3) = \frac{TWS(mg)}{V(m^3)}$$

Table 3.1 on the facing page shows the dust size range for each impactor stage.

	1 1	0
Stage No	Size range (μm)	Median (mm)
1	50 - 21.3	32.6
2	21.3 - 14.8	17.75
3	14.8 - 9.8	12.04
4	9.8 - 6.0	7.67
5	6.0 - 3.5	4.58
6	3.5 - 1.55	2.33
\mathbf{F}	1.55 - 0.1	0.39

 Table 3.1.:
 Marple Impactor Dust Size Range

In order to determine ${\cal MMAD}$ the following calculations should be carried out:

1. Determine a cumulative % 'less than' for each stage:

Stage 1:

$$Cum.\% < size = \left(\frac{\sum_{i=2}^{7} (WTi_{POST} - WTi_{PRE})}{TWS}\right) \times 100$$

Stage 2:

$$Cum.\% < size = \left(\frac{\sum_{i=3}^{7} (WTi_{POST} - WTi_{PRE})}{TWS}\right) \times 100$$

Stage 3:

$$Cum.\% < size = \left(\frac{\sum_{i=4}^{7} (WTi_{POST} - WTi_{PRE})}{TWS}\right) \times 100$$

Stage 4:

$$Cum.\% < size = \left(\frac{\sum_{i=5}^{7} (WTi_{POST} - WTi_{PRE})}{TWS}\right) \times 100$$

Stage 5:

$$Cum.\% < size = \left(\frac{\sum_{i=6}^{7} (WTi_{POST} - WTi_{PRE})}{TWS}\right) \times 100$$

Stage 6:

$$Cum.\% < size = \left(\frac{(WTf_{POST} - WTf_{PRE})}{TWS}\right) \times 100$$

Stage F:

$$Cum.\% < size = 0$$

- 2. Since all median values are known, calculate the natural logarithm of M for each stage: Stage 1: $\ln(M1) = \ln 32.6 = 3.484$ Stage 2: $\ln(M2) = \ln 17.75 = 2.876$ Stage 3: $\ln(M3) = \ln 12.04 = 2.488$ Stage 4: $\ln(M4) = \ln 7.67 = 2.037$ Stage 5: $\ln(M5) = \ln 4.58 = 1.522$ Stage 6: $\ln(M6) = \ln 2.33 = 0.846$ Stage F: $\ln(Mf) = \ln 0.39 = -0.942$
- 3. Calculate values $TWi \times \ln(Mi)$ for each stage and summarise them:

$$\sum_{i=1}^{7} TWi \times \ln(Mi)$$

4. Then the MMAD value could be calculated as follows:

$$MMAD = exp\left(\frac{\left(\sum_{i=1}^{7} \left(TWi \times \ln(Mi)\right)\right)}{TWS}\right)$$

5. Geometric standard deviation (GSD) for the MMAD value should also be calculated:

$$GSD = exp\left(\sqrt{\frac{\left\{\sum_{i=1}^{7} \left(TWi \times \left(\ln\left(\frac{Mi}{MMAD}\right)\right)^{2}\right)\right\}}{TWS}}\right)}$$

3.1.1.1. Calculation example – MMAD

Data The sample was worn for 8 hours (480 minutes) and the 'pre-weights' and 'post-weights' are:

Stage 1: $WT1_{PRE} = 28.58 \text{ mg}, WT1_{POST} = 44.05 \text{ mg}$

- Stage 2: $WT2_{PRE} = 27.27 \text{ mg}, WT2_{POST} = 43.94 \text{ mg}$
- Stage 3: $WT3_{PRE} = 27.25 \text{ mg}, WT3_{POST} = 32.12 \text{ mg}$
- Stage 4: $WT4_{PRE} = 27.33 \text{ mg}, WT4_{POST} = 27.77 \text{ mg}$
- Stage 5: $WT5_{PRE} = 26.75 \text{ mg}, WT5_{POST} = 27.01 \text{ mg}$
- Stage 6: $WT6_{PRE} = 26.53 \text{ mg}, WT6_{POST} = 26.67 \text{ mg}$
- Stage F: $WTf_{PRE} = 10.31 \text{ mg}, WTf_{POST} = 10.47 \text{ mg}$

Solution

1. The volume of the sample is

$$\frac{480\,minutes \times 2\,litres\,per\,minute}{1000} = 0.96\,m^3$$

2. The total weight of each stage is:

Stage 1: $TW1 = WT1_{POST} - WT1_{PRE} = 44.05 - 28.58 = 15.47$ mg Stage 2: $TW2 = WT2_{POST} - WT2_{PRE} = 43.94 - 27.27 = 16.67$ mg Stage 3: $TW3 = WT3_{POST} - WT3_{PRE} = 32.12 - 27.25 = 4.87$ mg Stage 4: $TW4 = WT4_{POST} - WT4_{PRE} = 27.77 - 27.33 = 0.44$ mg Stage 5: $TW5 = WT5_{POST} - WT5_{PRE} = 27.01 - 26.75 = 0.26$ mg Stage 6: $TW6 = WT6_{POST} - WT6_{PRE} = 26.67 - 26.53 = 0.14$ mg Stage F: $TWf = WTf_{POST} - WTf_{PRE} = 10.47 - 10.31 = 0.16$ mg Total weight of the sample (TWS) is:

$$TWS = \sum_{i=1}^{7} (WTi_{POST} - WTi_{PRE})$$

$$=\sum_{i=1}^{7} TW_{i,i} = 15.47 + 16.67 + 4.87 + 0.44 + 0.26 + 0.14 + 0.16 = 38.01 \, mg$$

3. The total dust concentration is

$$\frac{38.01mg}{0.96m^3} = 39.59mg/m^3$$

4. Determine a cumulative % less than for each stage:

Stage 1:

$$Cum.\% < size = \left[\frac{(TW2 + TW3 + TW4 + TW5 + TW6 + TWf)}{TWS}\right] \times 100$$
$$= \left[\frac{22.54}{38.01}\right] \times 100 = 59.30\%$$

Stage 2:

$$Cum.\% < size = \left[\frac{(TW3 + TW4 + TW5 + TW6 + TWf)}{TWS}\right] \times 100 = \left[\frac{5.87}{38.01}\right] \times 100$$

$$= 15.44\%$$

Stage 3:

$$Cum.\% < size = \left[\frac{(TW4 + TW5 + TW6 + TWf)}{TWS}\right] \times 100 = \left[\frac{1.00}{38.01}\right] \times 100 = 2.63\%$$

Stage 4:

$$Cum.\% < size = \left[\frac{(TW5 + TW6 + TWf)}{TWS}\right] \times 100 = \left[\frac{0.56}{38.01}\right] \times 100 = 2.63\%$$

Stage 5:

$$Cum.\% < size = \left[\frac{(TW6 + TWf)}{TWS}\right] \times 100 = \left[\frac{0.30}{38.01}\right] \times 100 = 0.79\%$$

Stage 6:

$$Cum.\% < size = \left[\frac{(TWf)}{TWS}\right] \times 100 = \left[\frac{0.16}{38.01}\right] \times 100 = 0.42\%$$

Stage F:

$$Cum.\% < size = 0.00\%$$

- 5. Natural logarithms for median values were calculated previously:
 - Stage 1: $\ln(M1) = \ln 32.6 = 3.484$ Stage 2: $\ln(M2) = \ln 17.75 = 2.876$ Stage 3: $\ln(M3) = \ln 12.04 = 2.488$ Stage 4: $\ln(M4) = \ln 7.67 = 2.037$ Stage 5: $\ln(M5) = \ln 4.58 = 1.522$ Stage 6: $\ln(M6) = \ln 2.33 = 0.846$ Stage F: $\ln(Mf) = \ln 0.39 = -0.942$
- 6. Calculate values $TWi \times ln(Mi)$ for each stage and summarise them:

Stage 1:
$$TW1 \times \ln(M1) = 15.47 \times 3.484 = 53.902$$

Stage 2: $TW2 \times \ln(M2) = 16.67 \times 2.876 = 47.949$
Stage 3: $TW3 \times \ln(M3) = 4.87 \times 2.488 = 12.118$
Stage 4: $TW4 \times \ln(M4) = 0.44 \times 2.037 = 0.896$
Stage 5: $TW5 \times \ln(M5) = 0.26 \times 1.522 = 0.396$
Stage 6: $TW6 \times \ln(M6) = 0.14 \times 0.846 = 0.118$
Stage F: $TWf \times \ln(Mf) = 0.16 \times (-0.942) = -0.151$
 $\sum_{i=1}^{7} TWi \times \ln(Mi) = 53.902 + 47.949 + 12.118 + 0.896 + 0.396 + 0.118 - 0.151 = 115.229$

7. Calculate the MMAD value:

$$MMAD = exp\left(\frac{\left(\sum_{i=1}^{7} (TWi \times \ln(Mi))\right)}{TWS}\right)$$
$$= exp\left(\frac{115.229}{38.01}\right)$$
$$= exp\left(3.03\right) = 20.7$$

8. Calculate the standard deviation for the MMAD value: Calculate values for $TW1 \times \left(\ln\left(\frac{M1}{MMAD}\right)\right)^2$ and summarise them: Stage 1:

$$TW1 \times \left(\ln\left(\frac{M1}{MMAD}\right)\right)^2 = 15.47 \times \left(\ln\left(\frac{32.6}{20.7}\right)\right)^2 = 15.47 \times 0.206 = 3.187;$$

Stage 2:

$$TW2 \times \left(\ln\left(\frac{M2}{MMAD}\right)\right)^2 = 16.67 \times \left(\ln\left(\frac{17.75}{20.7}\right)\right)^2 = 16.67 \times 0.024 = 0.4009$$

Stage 3:

$$TW3 \times \left(\ln\left(\frac{M3}{MMAD}\right)\right)^2 = 4.87 \times \left(\ln\left(\frac{12.04}{20.7}\right)\right)^2 = 4.87 \times 0.294 = 1.432;$$

Stage 4:

$$TW4 \times \left(\ln\left(\frac{M4}{MMAD}\right)\right)^2 = 0.44 \times \left(\ln\left(\frac{7.67}{20.7}\right)\right)^2 = 0.44 \times 0.986 = 0.434;$$

Stage 5:

$$TW5 \times \left(\ln\left(\frac{M5}{MMAD}\right)\right)^2 = 0.26 \times \left(\ln\left(\frac{4.58}{20.7}\right)\right)^2 = 0.26 \times 2.275 = 0.591;$$

Stage 6:

$$TW6 \times \left(\ln\left(\frac{M6}{MMAD}\right)\right)^2 = 0.14 \times \left(\ln\left(\frac{2.33}{20.7}\right)\right)^2 = 0.14 \times 4.771 = 0.668;$$

Stage F:

$$TWf \times \left(\ln\left(\frac{Mf}{MMAD}\right)\right)^2 = 0.16 \times \left(\ln\left(\frac{0.39}{20.7}\right)\right)^2 = 0.16 \times 15.775 = 2.524;$$

Sum for all stages:

$$\sum_{i=1}^{7} TWi \times \left(\ln \left(\frac{Mi}{MMAD} \right) \right)^2 \dots$$

= 3.187 + 0.400 + 1.432 + 0.434 + 0.591 + 0.668 + 2.524 = 9.236

Then the standard deviation will be:

$$GSD = exp\left(\sqrt{\frac{\left\{\sum_{i=1}^{7} \left(TWi \times \left(\ln\left(\frac{Mi}{MMAD}\right)\right)^{2}\right)\right\}}{TWS}}\right)$$
$$GSD = exp\left(\sqrt{\frac{9.236}{TWS}}\right)$$

Therefore the Mass Median Aerodynamic Diameter (MMAD) is 20.7 ± 1.6 .

Resources Safety, Department of Mines and Petroleum

3.1.2. AMAD and associated calculations

Before the calculation the *minimum detection limit* (MDL) of the equipment in use must be established. MDL value is expressed in milliBecquerel (mBq).

The MDL for each impactor stage is calculated as follows:

$$MDLi = \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{Bc}{(Bt \times 60)} \times (Ct \times 60) \times \left(1 + \left(\frac{Ct}{Bt}\right)\right)}\right)}{Eff \times Ct \times 60}\right\} \times 1000$$

where:

MDLi = minimum detection limit of the equipment in use for the stage i for the counting time Ct;

Bc = number of counts from background for the background counting time Bt; Bt = background count time (usually 900 minutes);

Ct =counting time (e.g. 60 minutes for stages 1–4, 100 minutes for stages 5 and 6 and 200 minutes for the stage F);

Eff = efficiency of the alpha-spectrometer.

3.1.2.1. Calculation example - minimum detection limits

Data Impactor stages will be counted in two different alpha-spectrometer chambers.

Background counting results are:

Chamber 'A': 42 counts in 900 minutes

Chamber 'B': 37 counts in 900 minutes

Efficiency was determined:

Chamber 'A' Eff = 35.9%

Chamber 'B' Eff = 31.5%

Stages will be counted for 60, 100 and 200 minutes.

Solution MDL should be determined for each chamber for three different counting periods: Chamber 'A', 60 minutes count:

$$MDLi = \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{Bc}{(Bt \times 60)} \times (Ct \times 60) \times (1 + \left(\frac{Ct}{Bt}\right))}\right)}{Eff \times Ct \times 60}\right)}{Eff \times Ct \times 60} \right\} \times 1000$$
$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{42}{(900 \times 60)} \times (60 \times 60) \times (1 + \left(\frac{60}{900}\right))}\right)}{0.359 \times 60 \times 60}\right)}{0.359 \times 60 \times 60} \right\} \times 1000$$
$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{2.986}\right)\right)}{1292.4}\right\} \times 1000 \approx 7 \, mBq$$

Chamber 'A', 100 minutes count:

$$MDLi = \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{Bc}{(Bt \times 60)} \times (Ct \times 60) \times (1 + \left(\frac{Ct}{Bt}\right)}\right)\right)}{Eff \times Ct \times 60}\right\} \times 1000$$

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$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{42}{(900 \times 60)} \times (100 \times 60) \times (1 + \left(\frac{100}{900}\right)}\right)\right)}{0.359 \times 100 \times 60} \right\} \times 1000$$
$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{5.185}\right)\right)}{2154} \right\} \times 1000 \approx 5 \, mBq$$

Chamber 'A', 200 minutes count:

$$MDLi = \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{Bc}{(Bt \times 60)} \times (Ct \times 60) \times (1 + \left(\frac{Ct}{Bt}\right))}\right)}{Eff \times Ct \times 60}\right\} \times 1000$$
$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{42}{(900 \times 60)} \times (200 \times 60) \times (1 + \left(\frac{200}{900}\right))}\right)}{0.359 \times 200 \times 60}\right\} \times 1000$$
$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{11.407}\right)\right)}{4308}\right\} \times 1000 \approx 3 \, mBq$$

Chamber 'B', 60 minutes count:

$$MDLi = \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{Bc}{(Bt \times 60)} \times (Ct \times 60) \times (1 + \left(\frac{Ct}{Bt}\right))}\right)}{Eff \times Ct \times 60}\right)}{\left(25000 \times 600\right)} \right\} \times 1000$$
$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{37}{(900 \times 60)} \times (60 \times 60) \times (1 + \left(\frac{60}{900}\right))}\right)}{0.315 \times 60 \times 60}\right)}{0.315 \times 60 \times 60} \right\} \times 1000$$
$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{2.631}\right)\right)}{1134}\right\} \times 1000 \approx 7 \, mBq$$

Chamber 'B', 100 minutes count:

$$MDLi = \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{Bc}{(Bt \times 60)} \times (Ct \times 60) \times (1 + \left(\frac{Ct}{Bt}\right))}\right)}{Eff \times Ct \times 60}\right)}{\left(3.29 \times \sqrt{\frac{37}{(900 \times 60)} \times (100 \times 60) \times (1 + \left(\frac{100}{900}\right))}\right)}}\right\} \times 1000$$
$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{37}{(900 \times 60)} \times (100 \times 60) \times (1 + \left(\frac{100}{900}\right)\right)}\right)}{0.315 \times 100 \times 60}\right\} \times 1000 \approx 5 \, mBq$$

Chamber 'B', 200 minutes count:

$$MDLi = \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{Bc}{(Bt \times 60)} \times (Ct \times 60) \times (1 + \left(\frac{Ct}{Bt}\right)}\right)\right)}{Eff \times Ct \times 60}\right\} \times 1000$$

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$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{\frac{37}{(900 \times 60)} \times (200 \times 60) \times (1 + \left(\frac{200}{900}\right)}\right)\right)}{0.315 \times 200 \times 60} \right\} \times 1000$$
$$= \left\{ \frac{\left(3 + \left(3.29 \times \sqrt{10.049}\right)\right)}{1134} \right\} \times 1000 \approx 4 \, mBq$$

Therefore, minimum detection limits are shown in Table 3.2 :

	Table 3.2.: Minimur	n Detection Limits (:	mBq)
	60 minutes count	100 minutes count	200 minutes count
Chamber 'A'	7	5	3
Chamber 'B'	7	5	4

The following parameters are required for further calculations:

- Background counts for the each impactor stage i;
- Efficiency for the each impactor stage i;
- Number of counts for the each impactor stage i; and
- Sampling time.
- 1. The volume (V) in cubic metres (m^3) of the sample was calculated previously.

The 'net counted' *activity* (in mBq) is calculated for each stage as follows:

$$Ai = \left(\frac{\left(\frac{Cc}{Ct \times 60}\right) - \left(\frac{Bc}{Bt \times 60}\right)}{Eff}\right) \times 1000$$

where:

Ai = activity of the stage i (in milliBecquerels);

Cc = number of counts from the stage i for the counting time Ct;

Ct =counting time for the stage i;

Bc = number of counts from background for the background counting time Bt;

Bt = background count time (usually 900 minutes);

Eff = efficiency of the alpha-spectrometer.

- 1. The value obtained must be then compared with the respective 'Minimum Detection Limit'. If the sample count does not exceed the MDL then the MDL must be substituted for the sample count in the calculation. In other words, if the stage 'net counted' activity will be 5 milliBecquerel (with the MDL = 7 mBq), the value of 7 mBq should be used in all following calculations. If the 'net counted' activity on three or more stages is less than MDL, the sample is invalid.
- 2. The activity of the sample is calculated as follows:
- 3. Then the dust activity concentration is determined as follows:

$$Ac \left(mBq/m^3\right) = \frac{A \left(mBq\right)}{V(m^3)}$$

3.1.2.2. Calculation example – activity concentration

Data The sample was worn for 480 minutes and the flow rate of the sampler was 2 litres per minute.

		Table 3.3.: (Counting results		
Stage No	${f Backgrd.}\ {f counts}{f (Bc)}$	$\begin{array}{c} \text{Backgrd. time} \\ \text{(Bt)} \end{array}$	Efficiency (Eff)	Counts (Cc)	Count time (Ct)
1	42	900	0.359	775	60
2	37	900	0.315	291	60
3	42	900	0.359	162	60
4	42	900	0.359	57	60
5	42	900	0.359	45	100
6	42	900	0.359	19	100
f	37	900	0.315	43	200

A set of counting results are listed in Table 3.3:

Solution

- 1. The volume of the sample is: 480 min \times 2 litres per min = 960 litres = 0.96 m³.
- 2. 'Net counted' activity for each stage is:

$$\begin{split} A1 &= \left(\frac{\left(\frac{Cc}{Ct\times60}\right) - \left(\frac{Bc}{Bt\times60}\right)}{Eff}\right) \times 1000 = \left(\frac{\left(\frac{775}{60\times60}\right) - \left(\frac{42}{900\times60}\right)}{0.359}\right) \times 1000 = 597 \, mBq \\ A2 &= \left(\frac{\left(\frac{Cc}{Ct\times60}\right) - \left(\frac{Bc}{Bt\times60}\right)}{Eff}\right) \times 1000 = \left(\frac{\left(\frac{291}{60\times60}\right) - \left(\frac{37}{900\times60}\right)}{0.315}\right) \times 1000 = 254 \, mBq \\ A3 &= \left(\frac{\left(\frac{Cc}{Ct\times60}\right) - \left(\frac{Bc}{Bt\times60}\right)}{Eff}\right) \times 1000 = \left(\frac{\left(\frac{162}{60\times60}\right) - \left(\frac{42}{900\times60}\right)}{0.359}\right) \times 1000 = 123 \, mBq \\ A4 &= \left(\frac{\left(\frac{Cc}{Ct\times60}\right) - \left(\frac{Bc}{Bt\times60}\right)}{Eff}\right) \times 1000 = \left(\frac{\left(\frac{57}{60\times60}\right) - \left(\frac{42}{900\times60}\right)}{0.359}\right) \times 1000 = 42 \, mBq \\ A5 &= \left(\frac{\left(\frac{Cc}{Ct\times60}\right) - \left(\frac{Bc}{Bt\times60}\right)}{Eff}\right) \times 1000 = \left(\frac{\left(\frac{45}{100\times60}\right) - \left(\frac{42}{900\times60}\right)}{0.359}\right) \times 1000 = 19 \, mBq \\ A6 &= \left(\frac{\left(\frac{Cc}{Ct\times60}\right) - \left(\frac{Bc}{Bt\times60}\right)}{Eff}\right) \times 1000 = \left(\frac{\left(\frac{19}{100\times60}\right) - \left(\frac{42}{900\times60}\right)}{0.359}\right) \times 1000 = 7 \, mBq \end{split}$$

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$$Af = \left(\frac{\left(\frac{Cc}{Ct\times60}\right) - \left(\frac{Bc}{Bt\times60}\right)}{Eff}\right) \times 1000 = \left(\frac{\left(\frac{43}{200\times60}\right) - \left(\frac{37}{900\times60}\right)}{0.315}\right) \times 1000 = 9 \, mBq$$

Table 3.4 shows the comparison with MDL for each stage (MDL values were calculated previously for both chambers and all counting times):

Table 3.4	l.: Compar	ison with	MDL for	each stag	е.		
Stage	1	2	3	4	5	6	f
'Net counted' activity (mBq)Ai	597	254	123	42	19	7	9
MDL (mBq)	7	7	7	7	5	5	4
Comparison	Ai > MDL	$Ai{>}MDL$	$Ai{>}MDL$	Ai > MDL	Ai > MDL	Ai > MDL	Ai > MDL

Therefore, this sample is valid for the AMAD calculation.

3. The activity of the sample is:

$$\sum_{i=1}^{7} A_i = 597 + 254 + 123 + 42 + 19 + 7 + 9 = 1051 \, mBq$$

4. The dust activity concentration is determined as follows:

$$Ac (mBq/m^3) = \frac{A (mBq)}{V(m^3)} = \frac{1051mBq}{0.96m^3} = 1095mBq/m^3 = 1.095Bq/m^3$$

In order to determine AMAD the following calculations should be carried out:

1. Determine a *cumulative* % 'less than' for each stage:

Stage 1:

$$Cum.\% < size = \left(\frac{\sum_{i=2}^{7} Ai}{A}\right) \times 100$$

Stage 2:

$$Cum.\% < size = \left(\frac{\sum_{i=3}^{7} Ai}{A}\right) \times 100$$

Stage 3:

$$Cum.\% < size = \left(\frac{\sum_{i=4}^{7} Ai}{A}\right) \times 100$$

Stage 4:

$$Cum.\% < size = \left(\frac{\displaystyle\sum_{i=5}^{7} Ai}{A}\right) \times 100$$

Stage 5:

$$Cum.\% < size = \left(\frac{\sum_{i=6}^{7} Ai}{A}\right) \times 100$$

Stage 6:

$$Cum.\% < size = \left(\frac{Af}{A}\right) \times 100$$

Stage F:

$$Cum.\% < size = 0$$

- 2. Since all median values are known, calculate the natural logarithm of M for each stage:
 - Stage 1: $\ln(M1) = \ln 32.6 = 3.484$ Stage 2: $\ln(M2) = \ln 17.75 = 2.876$ Stage 3: $\ln(M3) = \ln 12.04 = 2.488$ Stage 4: $\ln(M4) = \ln 7.67 = 2.037$ Stage 5: $\ln(M5) = \ln 4.58 = 1.522$ Stage 6: $\ln(M6) = \ln 2.33 = 0.846$ Stage F: $\ln(Mf) = \ln 0.39 = -0.942$
- 3. Calculate values Ai \times ln(Mi) for each stage and summarise them:

$$\sum_{i=1}^{7} Ai \times \ln\left(Mi\right)$$

4. Then the AMAD value could be calculated as follows:

$$AMAD = exp\left(\frac{\left(\sum_{i=1}^{7} Ai \times \ln(Mi)\right)}{A}\right)$$

5. Geometric standard deviation (GSD) for the AMAD value should also be calculated:

$$GSD = exp\left(\sqrt{\frac{\left\{\sum_{i=1}^{7} \left(Ai \times \left(\ln\left(\frac{Mi}{AMAD}\right)\right)^{2}\right)\right\}}{A}}\right)}$$

3.1.2.3. Calculation example – AMAD and GSD

Data The following activities were calculated for each stage:

A1 = 597 mBq A2 = 254 mBq A3 = 123 mBq A4 = 42 mBq A5 = 19 mBq A6 = 7 mBqAf = 9 mBq

Therefore the total activity of the sample equals $1052 \ mBq$.

Solution

1. Determine a *cumulative* % *less than* for each stage:

Stage 1:

$$Cum.\% < size = \left[\frac{(A2 + A3 + A4 + A5 + A6 + Af)}{A}\right] \times 100 = \left[\frac{454}{1052}\right] \times 100 = 43.16\%$$

Stage 2:

$$Cum.\% < size = \left[\frac{(A3 + A4 + A5 + A6 + Af)}{A}\right] \times 100 = \left[\frac{200}{1052}\right] \times 100 = 19.01\%$$

Stage 3:

$$Cum.\% < size = \left[\frac{(A4 + A5 + A6 + Af)}{A}\right] \times 100 = \left[\frac{77}{1052}\right] \times 100 = 7.32\%$$

Stage 4:

$$Cum.\% < size = \left[\frac{(A5 + A6 + Af)}{A}\right] \times 100 = \left[\frac{35}{1052}\right] \times 100 = 3.33\%$$

Stage 5:

$$Cum.\% < size = \left[\frac{(A6 + Af)}{A}\right] \times 100 = \left[\frac{16}{1052}\right] \times 100 = 1.52\%$$

Stage 6:

$$Cum.\% < size = \left[\frac{Af}{A}\right] \times 100 = \left[\frac{9}{1052}\right] \times 100 = 0.86\%$$

Stage F:

$$Cum.\% < size = 0.00\%$$

2. Natural logarithms for median values were calculated previously:

```
Stage 1: \ln(M1) = \ln 32.6 = 3.484

Stage 2: \ln(M2) = \ln 17.75 = 2.876

Stage 3: \ln(M3) = \ln 12.04 = 2.488

Stage 4: \ln(M4) = \ln 7.67 = 2.037

Stage 5: \ln(M5) = \ln 4.58 = 1.522

Stage 6: \ln(M6) = \ln 2.33 = 0.846

Stage F: \ln(Mf) = \ln 0.39 = -0.942

3. Calculate values Ai × \ln(Mi) for each stage and summarise them:

Stage 1: A1 × \ln(M1) = 597 \times 3.484 = 2079.948
```

Stage 2: $A2 \times ln(M2) = 254 \times 2.876 = 730.504$ Stage 3: $A3 \times ln(M3) = 123 \times 2.488 = 306.024$ Stage 4: $A4 \times ln(M4) = 42 \times 2.037 = 85.554$ Stage 5: $A5 \times ln(M5) = 19 \times 1.522 = 28.918$ Stage 6: $A6 \times ln(M6) = 7 \times 0.846 = 5.922$ Stage F: $Af \times ln(Mf) = 9 \times (-0.942) = -8.478$

 $= Ai \times \ln(Mi) = 2079.948 + 703.504 + 306.024 + 85.554 + 28.918 + 5.922 - 8.478 = 3228.392$

4. Calculate the AMAD value:

$$AMAD = exp\left(\frac{\left(\sum_{i=1}^{7} Ai \times \ln(Mi)\right)}{A}\right)$$

$$= exp\left(\frac{3228.392}{1052}\right) = 21.5$$

5. Calculate the standard deviation for the AMAD value: Calculate values for:

$$\sum_{i=1}^{7} Ai \times \left(\ln \left(\frac{Mi}{AMAD} \right) \right)^2$$

and then summarise them:

Stage 1:

$$A1 \times \left(\ln \left(\frac{M1}{AMAD} \right) \right)^2 = 597 \times \left(\ln \left(\frac{32.6}{21.5} \right) \right)^2 = 597 \times 0.173 = 103.281$$

Stage 2:

$$A2 \times \left(\ln \left(\frac{M2}{AMAD} \right) \right)^2 = 254 \times \left(\ln \left(\frac{17.75}{21.5} \right) \right)^2 = 254 \times 0.037 = 9.398$$

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Stage 3:

$$A3 \times \left(\ln\left(\frac{M3}{AMAD}\right)\right)^2 = 123 \times \left(\ln\left(\frac{12.04}{21.5}\right)\right)^2 = 123 \times 0.336 = 41.328$$

Stage 4:

$$A4 \times \left(\ln\left(\frac{M4}{AMAD}\right)\right)^2 = 42 \times \left(\ln\left(\frac{7.67}{21.5}\right)\right)^2 = 42 \times 1.062 = 44.604$$

Stage 5:

$$A5 \times \left(\ln\left(\frac{M5}{AMAD}\right)\right)^2 = 19 \times \left(\ln\left(\frac{4.58}{21.5}\right)\right)^2 = 19 \times 2.391 = 45.429$$

Stage 6:

$$A6 \times \left(\ln\left(\frac{M6}{AMAD}\right)\right)^2 = 7 \times \left(\ln\left(\frac{2.33}{21.5}\right)\right)^2 = 7 \times 4.938 = 34.566$$

Stage F:

$$Af \times \left(\ln\left(\frac{Mf}{AMAD}\right)\right)^2 = 9 \times \left(\ln\left(\frac{0.39}{21.5}\right)\right)^2 = 9 \times 16.077 = 144.693$$

Sum for all stages :

$$\sum_{i=1}^{7} Ai \times \left(\ln \left(\frac{Mi}{AMAD} \right) \right)^2$$

= 103.281 + 9.398 + 41.328 + 44.604 + 45.429 + 34.566 + 144.693 = 423.299

Then the standard deviation will be:

$$GSD = exp\left(\sqrt{\frac{\left\{\sum_{i=1}^{7} \left(Ai \times \left(\ln\left(\frac{Mi}{AMAD}\right)\right)^{2}\right)\right\}}{A}}\right)}\right)$$

$$= exp\left(\sqrt{\frac{423.299}{A}}\right) = exp\left(\sqrt{\frac{423.299}{1052}}\right) = 1.9$$

Therefore the Activity Median Aerodynamic Diameter (AMAD) is 21.5±1.9

3.2. Excel spreadsheet for data processing

An Excel spreadsheet has been developed in order to the simplify calculations and minimise errors. Data should be entered into the appropriate fields to calculate the values. The program user interface and formulae are shown in Figures B.2 on page 27, B.3 on page 28, B.4 on page 29, and B.5 on page 30.

The sample Excel Spreadsheet is embedded in the electronic version of this document and may be run from here or saved onto your computer. This spreadsheet is free software; you can redistribute it and/or modify it. The software is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.

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4. DMP AMAD approval policy

4.1. Evaluation of impactor program results by the Regulator

Data generated from the impactor program must be submitted to DMP for approval. The data is compared with data generated by the personal air sampling (PAS) data in the Boswell Database to gain an indication of whether the impactor data is representative of the dust being encountered by workers. Often the dust levels collected by impactors in a plant measure higher concentrations than what is reported in Boswell. It is well known that impactors sample more dust that personal samplers. This is more evident in the gravimetric analysis data where the impactor data indicates that workers would be exposed to dust close to or above the recommended limit for nuisance dust, 10mg/m³. This higher loading of dust would affect the detection of alpha particles in the evaluation of radiometric impactor data. Better results can be achieved by specifically instructing employees on the method of wearing an impactor and how to avoid coarse particles (mineral spillage entering the sampler. Where care is taken by employees wearing an impactor, mass concentrations of dust measured with a personal impactor can be compatible with the levels obtained by the PAS program.

For the impactor data to be used as a means for determining the AMAD of the dust for converting the results of the dust for converting the results of the PAS to an internal dose, the two sampling methods should be representative of the same dust distributions. It is also important to be aware that impactors are not approved by the Australian Standard [4].

However, the policy is that when it is apparent that the dust in a work area has an AMAD in excess of 10 μ m, a default particle size AMAD value of 10 μ m is approved for use in the assessment of the committed effective dose for a period of 12 months. Otherwise, the default AMAD is set at 5 μ m as recommended by ICRP 66 [5].

A. Appendix with a typical procedure for setting up a seven-stage impactor

- 1. All parts for the impactor assembly should be present seven stages, the impactor unit, the metal filter holder, inlet cowl and two screws.
- 2. All internal surfaces of the impactor and impactor stages should be free of dirt:
 - a) Each stage and impactor should be thoroughly wiped with detergent or alcohol, then brushed, wiped clean and completely dried;
 - b) The stages should be held onto a light to make sure that all slots are free of dirt and dust.
- 3. Plastic substrates should be put in the template and sprayed with silicone grease several hours before setting up to allow solvent to evaporate completely.
- 4. The filter used for the last stage should be placed in a clean container and left with lid slightly ajar overnight to come to equilibrium with the atmosphere.
- 5. The metal filter holder should be placed onto the bottom of the impactor unit.
- 6. The filter must be weighed to an accuracy of ± 0.01 mg and placed on the top of the metal filter holder. The bottom impactor stage (typically 'F') should be placed on the top of this.
- 7. The plastic substrate, previously sprayed with silicon grease, should be weighed to an accuracy of ± 0.01 mg and placed on the bottom stage ('F') so the holes match up. Then the stage No.6 should be placed on the top of this.
- 8. This process should continue for each stage, until the stage No.1, where, instead of the substrate, the inlet cowl is placed on the top.
- 9. The impactor should be tightened with two screws and assembled with the dust pump. The impactor is then worn in the same manner as ordinary dust sampling heads.
- 10. After the sampling impactor must be disassembled, each stage should be weighed to an accuracy of ± 0.01 mg and placed in the plastic petri dish for the radiometric analysis.
- 11. The following data should be recorded: number of the sample, date and time of sampling, wearer's name and occupation, and weight of each stage before and after sampling.
- 12. Each stage should be analysed in the same manner as 'ordinary' dust samples for alpha activity concentrations. Usually each stage is counted for 100 minutes. Counting times may increase to 300 minutes with decrease in dust concentrations.

B. Appendix with Excel spreadsheet views

1 Summer No		A	8	U	D	ш	ц	9	н	1	ſ
1 2 3 4 5 6 F a 0 10 2 2 2 2 2 3 4 5 10 4 5 10 4 5 10 4 10 5 10 4 10 5 10 4 10 5 10 4 10	-	SAMPLE No									Т
ℓ 32.53 37.37 36.75 10.31 10.47 ℓ 32.53 13.77 20.10 36.67 10.47 10.47 ℓ 32.13 15.44 2.63 0.44 0.25 0.14 0.16 ℓ 32.01 17.148 18.8 9.8 0.0 0.25 0.14 0.16 ℓ 32.61 17.15 12.04 7.67 4.58 2.33 0.39 0.30 ℓ 32.61 17.15 12.04 7.67 4.58 2.33 0.39 <th< td=""><td>2</td><td></td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>ц</td><td>Σ</td><td></td></th<>	2		1	2	3	4	5	6	ц	Σ	
e_{i} $i+105$ $i+321$ 2.17 2.01 2.667 10.17 n' ne_{i} 5.31 16.67 4.87 0.44 0.26 0.14 0.16 n' 5.36 1.173 $2.13, 4.18$ $1.48, 9.8$ $9.8, 6.6$ $6.0, -3.5$ $3.5, -155$ $1.55, 0.1$ n' $5.0, 21.3$ $2.13, -14.8$ $1.48, -9.8$ $9.8, -6.6$ 0.044 0.00 n' $0, -2.8$ $0.28, 0$ 0.039 0.399 0.399 0.399 0.399 n' 0.239 0.315 0.339 0.339 0.315 0.399 0.316 n' 0.399 0.315 0.339 0.335 0.315 0.399 n' 0.399 0.315 0.339 0.336 0.315 0.315 0.315 n' 0.35 0.315 0.339 0.335 0.315 0.315 0.315 n' 0.312 0.313	3	Pre-weight (mg)	28.58	27.27	27.25	27.33	26.75	26.53	10.31		1
IT/ (mg) 15.47 16.67 4.87 0.44 0.05 0.14 0.16 0 32.30 11.74 14.8 3 1.47 0.79 0.12 0.03 0 32.6 11.74 14.8 3 3.14 2.37 0.03 0 32.6 11.74 14.8 3 3.12 3.57 0.03 0 32.6 213 14.8 3 2.037 2.937 0.93 0 000	4	Post-weight (mg)	44.05	43.94	32.12	27.77	27.01	26.67	10.47		
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	5	Total weight [W] (mg)	15.47	16.67	4.87	0.44	0.26	0.14	0.16	38.01	
0 50-213 213-148 148-98 98-60 60-35 35-155 155-01 mi 32.6 17.75 12.04 7.67 4.58 2.039 0.39 mi 34.94 2.775 12.04 7.67 4.28 2.035 0.39 0.39 mi 900 900	9	Cum.% < size	59.30	15.44	2.63	1.47	0.79	0.42	0.00		
mult 32.6 17.5 12.04 7.67 45.8 2.33 0.39 mult 3.444 2.876 2.483 2.037 1.522 0.846 0.942 mult 3.444 2.876 2.483 2.037 1.522 0.846 0.942 mult 3.30 0.30 900 900 900 900 900 900 mult 3.30 0.339 0.339 0.339 0.339 0.315 0.315 0.315 mult 7 7 7 7 7 7 5 5 4 mult 77 7 7 7 7 7 7 9 9 ct/mbg/ 597 254 1123 42 19 7 9 9 mbg/ 597 254 123 44.939 45.022 36.93 36.03 36.93 36.93 36.93 36.93 36.93 36.93 36.93 36.93	1	Size range (nm)	50 - 21.3	21.3 - 14.8	14.8 - 9.8	9.8 - 6.0	6.0 - 3.5	3.5 - 1.55	1.55 - 0.1		
mem 3484 2876 2488 2037 1522 0846 0942 mem 42 33 42 42 42 43 339 0335 me me 000	8	Median [M] (nm)	32.6	17.75	12.04	7.67	4.58	2.33	0.39		
nut $+2$ 37 $+2$ 37 $+2$ 37 30 9000 900 900 <	0	[m[M]	3.484	2.876	2.488	2.037	1.522	0.846	-0.942		
me me mo	10	Background count	42	37	42	42	42	42	37		
mb 0.339 0.315 0.339 0.339 0.339 0.339 0.335 0.335 0.335 0.335 0.335 0.335 0.335 0.335 0.335 0.335 0.315 0	11	Background time (min)	006	006	006	006	006	006	006		
(p) (0) <t< td=""><td>12</td><td>Efficiency</td><td>0.359</td><td>0.315</td><td>0.359</td><td>0.359</td><td>0.359</td><td>0.359</td><td>0.315</td><td></td><td></td></t<>	12	Efficiency	0.359	0.315	0.359	0.359	0.359	0.359	0.315		
at (mBg) 7 7 7 7 7 7 7 5 5 5 4 4 rivity (mBg) 597 254 123 42 19 7 9 43 9 $4DL$ 254 123 42 19 7 9 9 $4DL$ 251 254 123 42 19 7 9 $4DL$ 201822 731833 306.505 85.400 28.404 56.20 8.663 ADE 216 9785 42.048 44.939 45.022 2.801 148.247 $BMD(14LAD)$ 101335 9785 42.048 43.939 45.023 2.863 70 ADE 201 11355 47.949 12.118 0.896 0.396 0.185 70 ADE 20.7 10.317 14.338 0.435 0.699 2.568 70 SDE 16 7 0 0.73 0.435	13	Count time (min)	60	60	60	60	100	100	200		
Tris 291 162 57 45 19 7 9 currity (mBq) 597 254 123 42 19 7 9 cMDL (NO)? 597 254 123 42 19 7 9 cMDL (NO)? 597 254 123 42 19 7 9 add 4318 18.990 7.28 3.06.505 85.440 28.494 5.629 -8.663 add/(1/14121)) 101335 9.785 47.949 12.118 0.896 0.396 0.118 -0.151 MDD(1/141412)) 101335 9.785 47.949 12.118 0.896 0.396 0.118 -0.151 MDD(1/141412)) 101335 9.786 44.939 45.032 32.991 148.247 SD= 1.9 101335 0.401 14.38 0.396 0.396 0.181 MDD 33302 47.949 12.118 0.896 0.396 0.184 -0.151 SD= 1.9 31.71 0.435 0.3633 0.693 2	14	Min.Detect. Act (mBq)	7	7	7	7	5	5	4		
citivity (mBg) 597 254 123 42 19 7 9 citivity (mBg) 597 254 123 42 19 7 9 cMDL (NO)7 597 254 123 32.0 151 0.87 0.00 dBg) 4318 18.99 7.83 306.305 85.440 28.494 5.029 8.663 dBp 143.18 18.99 7.85 306.305 85.440 28.494 5.029 8.663 dBp 2081.852 711.863 306.305 85.440 28.494 5.029 8.663 dMD 101.335 9765 42.048 44.939 45.032 32.991 148.247 SMD 101.335 976 42.048 0.896 0.396 0.118 0.151 MD 101 1335 0.429 0.896 0.396 0.118 0.151 SMD 1.9 0.311 0.4101 1.438 0.435 0.593 0.069 2.526 SMD mMM 0.41 0.435 0.533 0.59	15	Counts	775	291	162	57	45	19	43		
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	16	Net counted Activity (mBq)	597	254	123	42	19	7	6		
mBg/limit 597 254 123 42 19 7 9 4318 18.99 7.28 329 151 0.87 0.00 416 13.18 18.99 7.28 32.99 1.51 0.87 0.00 $4D$ 2081.852 731.863 306.505 85.440 28.494 5.629 -8.663 $4D$ 21.6 9.78 42.048 44.939 45.032 32.991 148.247 $MpU/(AMD)$ 101335 9.76 47.949 12.118 0.896 0.396 0.118 -0.151 MD 33.902 47.949 12.118 0.896 0.396 0.118 -0.151 MD 3.171 0.401 1.438 0.435 0.593 0.669 2.526 MD 3.171 0.401 1.438 0.435 0.593 0.669 2.526 MD 3.171 0.401 1.438 0.435 0.593 0.669 2.526 MD MD MD MD MD MD MD MD	17	Is net activity <mdl (no)?<="" td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></mdl>									
43.18 18.90 7.28 3.29 1.51 0.87 0.00 2081.852 2081.852 731.863 306.505 85.440 28.494 5.629 8.663 8.663 $M(M)[AALD])$ 101.335 9.785 42.048 44.939 45.032 2.991 148.247 $M(M)[AALD])$ 101.335 9.785 42.048 44.939 45.032 32.991 148.247 $M(M)[AALD])$ 101.335 9.785 42.048 44.939 45.032 32.991 148.247 $S3902$ 47.949 12.118 0.896 0.396 0.18 0.151 MD 3171 0.401 1.438 0.435 0.969 2.526 2.526 ME 0.77 0.401 1.438 0.435 0.669 2.526 2.526 ME WOR $SHIFT$ 1.480 0.736 0.669 2.526 3.526 ME WOR $SHIFT$ 1.480 $2.514m$ 1.057 $3.74m$ 1.05 $3.74m$ </td <td>18</td> <td>Activity [A] (mBq)</td> <td>597</td> <td>254</td> <td>123</td> <td>42</td> <td>19</td> <td>7</td> <td>6</td> <td>1052</td> <td></td>	18	Activity [A] (mBq)	597	254	123	42	19	7	6	1052	
2081.852 731.863 306.505 85.440 28.494 5.629 -8.663 AD = 21.6 101.335 9.785 42.048 44.939 45.032 23.991 148.247 $M(M/(AMMD))$ 101.335 9.785 42.048 44.939 45.032 32.991 148.247 $N(M/(AMD))$ 101.335 9.785 42.048 44.939 6.502 32.991 148.247 SSD = 1.9 0.135 0.396 0.118 0.151 148.247 SSD = 1.9 0.135 0.396 0.118 0.151 0.151 MD 0.77 0.401 1.438 0.435 0.569 3.256 2.526 $MD(M/(MD))$ 3.171 0.401 1.438 0.435 0.569 2.526 2.526 $MD(M/(MD))$ 3.17 0.593 0.669 2.526 0.536 0.569 0.569 0.569 0.569 0.566 $MD(M/(M))$ $MD(M/(M))$ $SMPLE$ $COMT$ $D(M/M)$ <th< td=""><td>19</td><td>Cum.% < size</td><td>43.18</td><td>18.99</td><td>7.28</td><td>3.29</td><td>1.51</td><td>0.87</td><td>0.00</td><td></td><td></td></th<>	19	Cum.% < size	43.18	18.99	7.28	3.29	1.51	0.87	0.00		
AD 21.6 1.6 44.939 45.032 32991 148.247 $hi[Al/[AMAD]]$ 101335 9.785 42.048 44.939 45.032 32991 148.247 SD 1.9 0.1335 9.785 47.949 12.118 0.896 0.188 0.151 SD $3.33.902$ 47.949 12.118 0.896 0.396 0.118 0.151 SD 3.171 0.401 1.438 0.356 0.593 0.169 2.526 $hi[D]$ 3.171 0.401 1.438 0.435 0.593 0.669 2.526 $hi[D]$ 3.171 0.401 1.438 0.435 0.593 0.669 2.526 $hi[D]$ 1.6 1.438 0.435 0.593 0.669 2.526 SD 1.6 1.6 7.0 1.482 7.0 7.0 ME MOK 2.56 $3.1.0$ $1.1.76$ 7.0 7.0 $SMDL$ $D.0.0$ $3.0.0$ $3.1.0$ $7.$	20	{[A] *!n[M]}	2081.852	731.863	306.505	85.440	28.494	5.629	-8.663	3231.120	
hn[dn/(tAMAL)] 101335 9.785 42.048 44.939 45.032 32.991 148.247 $SD=$ 1.9 0.133 0.133 0.133 0.136 0.163 0.163 $SD=$ 1.9 33.902 47.949 12.118 0.896 0.396 0.118 0.0151 $AD=$ 20.7 0.401 1.438 0.435 0.593 0.669 2.526 $MiQ(JMAL2)]$ 3.171 0.401 1.438 0.435 0.593 0.669 2.526 $MiD(JMAL2)]$ 3.171 0.401 1.438 0.435 0.593 0.669 2.526 $MiD(JMAL2)]$ $MiD(MAL2)]$ $MiD(MMAD(MAD(MAD(MAD(MAD(MAD(MAD(MAD(MAD(M$	21	AMAD=	21.6								
SD= 19 1.9 1.18 0.896 0.118 0.118 0.151 $tAD=$ 20.7 3.71 0.401 1.2.118 0.896 0.396 0.118 0.151 $tAD=$ 20.7 3.71 0.401 1.438 0.435 0.593 0.669 2.526 M/M 1.6 1.438 0.435 0.593 0.669 2.526 SD= 1.6 7 7 7 7 7 SME WOKK SHFT T/ME (m/m) FLOW (pm) SAMPLE 0.0693 2.526 MD D.P.O. NGT 480 2 3.1.Jm 1095 MME D.P.O. NGT 480 2 3.1.Jm 1095 MD.L.Stages 100e D.P.O. NGT 480 2 1095 M.D.L.Stages 100e Intert 1 1 1 1 1 M.D.L.Stages 100e Intert 1 1 1 1 1 1 M.D.L.Stages 100e Inter Inter <td>22</td> <td></td> <td>101.335</td> <td>9.785</td> <td>42.048</td> <td>44.939</td> <td>45.032</td> <td>32.991</td> <td>148.247</td> <td>424.377</td> <td></td>	22		101.335	9.785	42.048	44.939	45.032	32.991	148.247	424.377	
4D= 53.902 47.949 12.118 0.896 0.396 0.118 -0.151 $t4D=$ 20.7 3.171 0.401 1.438 0.355 0.669 2.526 M/Mf M/M M/M M/M M/M $D.435$ 0.593 0.669 2.526 $SD=$ 1.6 0.401 1.438 0.435 0.593 0.669 2.526 $SD=$ 1.6 0.401 1.438 0.435 0.593 0.669 2.526 $SD=$ 1.6 M/M M/M M/M $D.10$	23		1.9						-		
$I_4D=$ 20.7 1.438 0.455 0.693 0.669 2.526 $M/M/(/////////////////////////////////$	24	{[W]nl*[W]}	53.902	47.949	12.118	0.896	0.396	0.118	-0.151	115.229	
	25	MMAD=	20.7								
GSD= 1.6 <th< td=""><td>26</td><td></td><td>3.171</td><td>0.401</td><td>1.438</td><td>0.435</td><td>0.593</td><td>0.669</td><td>2.526</td><td>9.232</td><td></td></th<>	26		3.171	0.401	1.438	0.435	0.593	0.669	2.526	9.232	
NAME WORK SHIFT TIME (min) FLOW (pm) SAMPLE COUNT Tot mBq/m3 1.Smith D.P.O. NGT 480 2 31.Jan 11Feb 1095 M.D.L.Stages none 1 1 1 1 1 1 M.D.L.Stages none MONALLY ENTERED DATA MANUALLY ENTERED DATA 1 1	27		1.6								
NAME WORK SHIFT TIME (min) ELOW (pm) SAMPLE COUNT Tot mBq/m3 1.Smith D.P.O. NGT 480 2 31.Jan 11.Feb 1095 M.D.L.Stages none 1 P.P.O. NGT 480 2 31.Jan 11.Feb 1095 M.D.L.Stages none 1 P.P.O. NGT 480 2 31.Jan 11.Feb 1095	28										
J.Smith D.P.O. NGT 480 2 31-Jan 11-Feb 1095 M.D.L.Stages - none	29		WORK	SHIFT	TIME (min)	FLOW (Ipm)	SAMPLE	COUNT	Tot mBq/m3	Tot mg/m3	
M.D.L.Stages - none	30		D.P.O.	NGT	480	2	31-Jan	11-Feb	1095	40	
M.D.L.Stages - none	31										-\
	32		1 auou								
	33		/								
	34		_						/		
	35										
	36					- 22					
	37			N A N		TEPEN D	N T N				
39 40	38					ו בעבה ה		1			
40	39										
	40				3						

Figure B.1.: The user interface of the Excel spreadsheet.

	4	a	
c	3 Charle Mo	-	
4	Didge 110.		2 22 22
3	3 Pre-weight (mg)	8C.87	7/7/
4	4 Post-weight (mg)	44.05	43.94
S	5 Total weight [W] (mg)	=(B4-B3)	_=C4.C3
9	Cum.% < size	=((C5+D5+E5+F5+G5+H5)/I5)*100	=((D5+E5+F5+G5+H5)/I5)*100
7	7 Size range (nm)	50-21.3	21.3 - 14.8
00	8 Median [M] (rm)	32.6	17.75
5	[W]u] 6	=LN(B8)	=LN(C8)
10	10 Background count	42	37
11	11 Background time (min)	006	006
12	12 Efficiency	0.359	0.315
13	13 Count time (min)	60	60
14	14 Min Detect. Act (mBq)	=(3+3.29*SQRT(B10/(B11*60)*(B13*60)*(1+(B13/B11)))/(B12*B13*60)*1	\$20RT(B10/(B11*60)*(B13*60)*(1+(B13/B11))))/(B12*B13*60)*100(=(3+3.29*S0RT(C10/(C11*60)*(C13*60)*(1+(C13/C11))))/(C12*C13*60)*1000
15	15 Counts	775	291
16	16 Net counted Activity (mBq)	=((B15/(B13*60)-(B10/(B11*60)))/B12)*1000	=((C15/(C13*60)-(C10/(C11*60)))/C12)*1000
17	17 Is net activity <mdl (no)?<="" td=""><td>=IF(B16>B14," ","NO")</td><td>=IF(C16>C14," ","NO")</td></mdl>	=IF(B16>B14," ","NO")	=IF(C16>C14," ","NO")
18	18 Activity [A] (mBq)	=E(B16>B14,B16,0)	=E(C16>C14,C16,0)
19	19 Cum.% < size	=((C18+D18+E18+F18+G18+H18)/118)*100	=((D18+E18+F18+G18+H18)/118)*100
20	$20 \{[A] * In[M]\}$	=B18*B9	=C18+C9
21	AMAD=	=EXP(120/118)	
22	{[A] *@SQ{Im([M]/[AMAD])}	=+(B18*(LN(B8/\$B\$21))^2)	=+(C18*(LN(C8/\$B\$21))^2)
23	GSD=	=EXP(SQRT(I22/118))	
24	24 {[W]*In[M]}	=B5*B9	=C5+C9
25	MM4D=	=EXP(I24/I5)	
26	{[IM] *@SQ{Im([M]/[MMAD])}}	=+(B5*(LN(B8/\$B\$25))^2)	=+(C5*(LN(C8/\$B\$25))^2)
27	GSD=	=EXP(SQRT(I26/IS))	
28			
29	NAME	WORK	SHIFT
30	J. Smith	D.P.O.	NGT
31			
32	M.D.L.Stages - none	none	
33			
34		CALCUL ATONS DESCRIPTED IN THE	
35		CALCULATIONS DESCRIBED IN THE	
36		PROCEDURE	
37			
38			

Figure B.2.: Spreadsheet calculations for Stage: $1\ \&\ 2.$

9.8 9.8 9.8 9.8 9.8 9.8 9.8 9.8		c	
3 3.15 =(D4-D3) =(E5+F5+G5+H5)/15)^{100} =(E3+F5+G5+H5)/15)^{100} =(E3+F5+G5+H5)/15)^{100} =L04D3 =L04D3 =L04D3 =L01B9 =(D16-D14, ***)^{100} =(D15-(D13+G0)/(D17:G0)^{100}(1+(D13*G0)^{1000}) =(D13+D0) =(D15-(D13+G0)(D11+60))/D12)+1000 =(D15-(D13+G0)(D11+60))/D12)+1000 =(D13+D0) =(D15+D14, ***)^{100} =(D15+D14, ***)^{100} =(D15+D14, ***)^{100} =(D15+D14, ***)^{100}			
12.33 27.33 27.33 -10.4.13 -16.4.E3 -16.4.E3 -10.4.13 -1.4.E3 -1.4.E3 -1.4.14 -1.4.E3 -1.4.E3 -1.4.15 -1.4.1.15 -1.4.1.15 -1.4.15 -1.4.1.15 -1.4.1.15 -1.4.15 -1.4.1.15 -1.4.1.15 -1.4.15 -1.4.1.15 -1.4.1.15 -1.4.15 -1.4.1.15 -1.4.1.15 -1.4.15 -1.4.1.15 -1.4.1.15 -1.4.15 -1.4.1.15 -			4
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		7.25	27.33
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		2.12	27.77
$ \begin{array}{c} -(\Gamma5+G5+H3)(H5)^{-1}(10) & -(\Gamma5+G5+H3)(H5)^{-1}(10) & 98.60 \\ 18.40 & -(\Gamma5+G5+H3)(H5)^{-1}(10) & 98.60 \\ 18.40 & -(10) & -(118.48 & -2) \\ 2.6 & -(116.40 & -($		-(D4-D3)	=(E4-E3)
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		-((E5+F5+G5+H5)/I5)*100	=((F5+G5+H5)/I5)*100
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	7	14.8 - 9.8	9.8 - 6.0
$\frac{-LN(E8)}{2} = \frac{-LN(E8)}{2} = \frac{1}{2} = \frac{2}{2} = $		2.04	7.67
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		±LN(D8)	=LN(E8)
900 9139 910 9139 910 9133 910 9133 9133 9133 9133 913 91	10	2	77
0.339 0.339 0.339 0.339 0.339 0.339 0.339 0.339 0.339 0.339 0.339 0.3317 0.3317 0.3317 0.331 0.331 0.331 0.331 0.331 0.331 0.331 0.331 0.331 0.331 0.331 0.331 0.331 0.331 0.33 0.33	11 5	8	000
60 60 60 12-3.23*50RT[010[011:60]/[013*60]/[100]2*0]760]/[100] 13-3.29*50RT[[100][11:60]/[12:60]/[100] 120-3.23*50RT[010[011:40]/[013*60]/[100] 13-3.29*50RT[[100][11:40]/[12:61]/[100] -(D15(013+60)/[011]*60]/[012]/[100] 13-3.29*50RT[[100][11:40]/[12:71]00] -(D15(013+61)/[100] -(C15(A13*60)/[11:40]/[13:71])/[012]/[100] -(D15(015-0114)/[100] -(C15(A13*61)/[100] -(D15(A113)/[13)*100 -(C15(A13*0)/[13:110) -(D18*(L100)\$58321])/2] -(C18+F118/I18)/[13)*100 -(D18*(L100)\$58321])/2] -(C18+F118)/[13)*100 -(D18*(L100)\$58321])/2] -(C18+F118)/[13)*100 (D5'(LN[D08\$58325])/2] -(E18*(L10[858525])/2] (D5'(LN[D08\$58325])/2] -(E18*(L10[858525])/2] (D5'(LN[D08\$5825])/2] -(E18*(L10) (D5'(LN[D08\$5825])/2] -(E5*(L10) (D5'(LN[D08)	12 (359	0.359
=[3+3.29*SQRT[D10/(D11*60]*[D13*60]*(1+[D13/D11]))/(D12*D13*60)*1000 162 =(D15/(D14,"","NO") =IF(D15/D14,"","NO") =IF(D16>D14,"","NO") =(E18+F18+G18+H18)/118)*100 =D18*D9 =+(D18*(LN(D8/\$B\$21))^2) =+(D18*(LN(D8/\$B\$21))^2) =+(D5*(LN(D8/\$B\$25))^2) =+(D5*(D5)^2) =+(D5*(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5)^2) =+(D5*(D5*(D5)^2) =+(D5*(D5)^2)	13	0	09
162 57 =(015/013*60)-(D1/1*60))/D12)*1000 =(E15/E13*60)-(E10/E11*60))/E12 =(F(6165E14,100) =(F(6165E14,E16,0)) =(F(6165E14,E16,0)) =(F(6165E14,E16,0)) =(F(165E14,E16,0)) =(F(6165E14,E16,0)) =(F(118+F13+C13+H18)/118)*100 =(F(118+F13+C13+H18)/118)*100 =05*19 =(F(118+F13+C13+H18)/118)*100 =105*10 TIME (min) 480 TIME (min) 480 PROCEDURE PROCEDURE 2		=(3+3.29*SQRT(D10/(D11*60)*(D13*60)*(1+(D13/D11))))/(D12*D13*60)*1000	=(3+3.29* SQRT(E10/(E11*60)*(E13*60)*(1+(E13/E11))))/(E12*E13*60)*1000
=(fc15(fc13+60),(D10(D11+60)))/D12)+1000 =F(D16>D14, ", "NO") =F(D16>D14, ", "NO") =F(D16>D14, ", "NO") =F(D16>D14, ", "NO") =F(D16>D14, ", "NO") =F(D16>D14, ", "NO") =F(D16>D14, ", "NO") =F(E16=E14, ", "NO", "NO") =F(E16=E14, ", "NO") =F(22
-iF(D16>D14, ", "NO") -iF(E16>E14, ", "NO") -E(D16>D14,D16,0) -iF(E16>E14, ", "NO") -=(D18*L13)*100 -=(E18*E16,0) -=(D18*C13+H18)/118)*100 -=(E18*E16,0) -=(D18*C13+H18)/118)*100 -=(E18*E16,0) -=(D18*C13)*2) -=(E18*E16,0) -=(D18*C13)*2) -=(E18*E16,0) -=(D18*C13)*2) -=(E18*E16,0) -=(D18*C13)*2) -=(E18*E16,0) -=(D5*(LN(D8/5B\$25))*2) -=(E18*E16,0) -=(D5*(LN(D8/5B\$25))*2) -=(E18*E16,0) -=(D5*(LN(D8/5B\$25))*2) -=(E5*E16,0) -=(D5*(LN(D8/5B\$25))*2) -=(E5*(LN(E8/5B\$25))*2) -=(D5*(LN(D8))*2) -=(+(D15/(D13*60)-(D10/(D11*60)))/D12)*1000	=(E15/E13*60)-(E10/(E11*60)))/E12)*1000
-=F(D16>D14,D16,0) ==F(E16>E14,E16,0) =(E18+F18+G18+H18)/118)*100 =(F(E16>E14,E16,0) =D18*D9 =(F(E16>E14,E16,0) =D18*D9 =(F(E16>E14,E16,0) =(F(E16>E14,E16,0) =(F(E16>E14,E16,0) =D18*D9 =(F(E16>E14,E16,0) =(F(E16>E14,E16,0) =(F(E16>E14,E16,0) =D18*D9 =(F(E16))/2) =(F(E16))/2) =(F(E16))/2) =D5*D9 =(E18*(LN(D8/\$B\$25))/2)) =D5*D9 =(E5*(LN(D8/\$B\$25))/2)) =(D5*(LN(D8/\$B\$25))/2)) =(E5*(LN(E8/\$B\$25))/2)) =(D5*(LN(D8/\$B\$25))/2)) =(E5*(LN(E8/\$B\$25))/2)) 480 =(E5*(LN(E8/\$B\$25))/2) A80 =(CALCULATIONS DESCRIBED IN /HE) PROCEDURE 2		-iF(D16>D14," ","NO")	=IF(E16>E14," ","NO")
-((E18+F18+C18+H18)/118)*100 -((F18+G18+H18)/118)*100 =D18*D9 -((F18+G18+H18)/118)*100 =1018*(LN(D8/\$B\$21))*2) =+(E18*(LN(E8/\$B\$21))*2) =+(D5*(LN(D8/\$B\$25))*2) ==(E5*E9 =+(D5*(E10*E10*E10*E10*E10*E10*E10*E10*E10*E10*	18	EE(D16>D14,D16,0)	=IF(E16>E14,F16,0)
■D18+D9 =E18+E9 =(D18*(LN(D8/5B521))*2) =(E18*(LN(E8/5B521))*2) =55*D9 =(E18*(LN(E8/5B525))*2) =(D5*(LN(D8/5B525))*2) =(E5*(LN(E8/5B525))*2) =(D5*(LN(D8/5B525))*2) =(E5*(LN(E8/5B525))*2) =105*(LN(D8/5B525))*2) =(E5*(LN(E8/5B525))*2) =105*(LN(D8/5B525))*2) =(E5*(LN(E8/5B525))*2) =105*(LN(D8/5B525))*2) =(E10*(DN))*2) =105*(LN(D8/5B525))*2) =(E1	19 =	+(E18+F18+G18+H18)/118)+100	=((F18+G18+H18)/118)*100
=+(D18*(LN(D8/\$B\$21))^2) =+(E18*(LN(E8/\$B\$21))^2) =+(E18*(LN(E8/\$B\$25))^2) =+(E5*(LN(E8/\$B\$25))^2) =+(E5*(LN(E8/\$B))^2) =+(E5*(LN(E8))^2) =+(E5*(LN(E8))^2) =+(E5*(LN(E8))^2) =+(E5*(LN(E8))^2) =+(E5*(LN(E8))^2) =+(E5*(LN(E8))^2) =+(E5*(LN(E8))^2) =+(E5*(LN(E8))^2) =+(E5*(LN(E8))^2) =+(E5*(LN(E8)))	20	DI8*D9	=E18*E9
=+(D18*(LN(D8/\$B\$21))^2) =+(E18*(LN(E8/\$B\$21))^2) =D5*D9 ==E5*E9 =+(D5*(LN(D8/\$B\$25))^2) ==+(E5*(LN(E8/\$B\$25))^2) =+(D5*(LN(D8/\$B\$25))^2) ==+(E5*(LN(E8/\$B\$25))^2) =+(D5*(LN(D8/\$B\$25))^2) ==+(E5*(LN(E8/\$B\$25))^2) ==+(E5*(LN(E8/\$B\$25)) ==+(E5*(LN(E8/\$B))) ==+(E5*(LN(E8*(E8)))) ==+(E5*(LN(E8))) ==+(E5*(E8)) ==+(E5*(LN(E8))) ==+(E5*(LN(E8)) ==+(E5*	21		
=D5*D9 =-(D5*(LN(D8/\$B\$25))^2) =-(D5*(LN(B8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2) =-(E5*(LN(E8/\$B\$25))^2)	22	-+(D18*(LN(D8/\$B\$21))^2)	=+(E18*(LN(E8/\$B\$21))^2)
=D5*D9 ==(D5*(LN(D8/\$B\$25))^2) ==(E5*C1)^2) ==(E5*C1)^2) ==(E5*(LN(E8/\$B\$25))^2) ==(E5*C1)^2 == (E5*(LN(E8/\$B\$25))^2) == (E5*C1)^2 = (E5*	23		
=+(D5*(LN(D8/\$B\$25))^2) =+(E5*(LN(E8/\$B\$25))^2) =+(E5*(LN(E8/\$B))^2) =+(E5*(LN(E8/\$B))) =+	24 =	D5*D9	=E5*E9
=+(D5*(LN(D8/\$B\$25))^2) =+(D5*(LN(E8/\$B\$25))^2) #80 #80 2 CALCULATIONS DESCRIBED IN /THE PROCEDURE PROCEDURE	25		
480 480 TIME (min) 2 CALCULATIONS DESCRIBED IN MHE PROCEDURE	26	-+(D5*(LN(D8/\$B\$25))^2)	=+(E5*(LN(E8/\$B\$25))^2)
480 480 CALCULATIONS DESCRIBED IN /THE PROCEDURE	27		
480 480 CALCULATIONS DESCRIBED IN /THE PROCEDURE	28		
480 CALCULATIONS DESCRIBED IN /THE PROCEDURE	29	TIME (min)	FLOW (Ipm)
CALCULATIONS DESCRIBED I PROCEDURE	30 4	80	2
CALCULATIONS DESCRIBED I PROCEDURE	31		
CALCULATIONS DESCRIBED I PROCEDURE	32		
CALCULATIONS DESCRIBED I PROCEDURE	33		
	34	CALCULATIONS DESCRIBED IN //HE	
37	35	PROCEDURE	
	37		

Figure B.3.: Spreadsheet calculations for Stage: 3 & 4.

	σ
2 5	Q
3 26.75	26.53
4 27.01	26.67
5 =(F4.F3)	=(G4-G3)
6 =((G5+H5)/15)*100	=((H5)/15)*100
7 6.0 - 3.5	3.5 - 1.55
8 4.58	233
9 =LN(F8)	=LN(G8)
10 42	190
11 900	00
12 0.359	0.359
13 100	100
14 =(3+3.29* SQRT(F10/(F11*60)*(F13*60)*(1+(F13/F11)))/(F12*F13*60)*1000	=(3+3.29* SQRT(G10/(G11*60)*(G13*60)*(1+(G13/G11)))/(G12*G13*60)*1000
15 45	19 DI
16 =((F15/(F13*60)-(F10/(F11*60)))/F12)*1000	311*60)))/G12)*1000
17 =IF(F16>F14," ","NO")	
18 =IF(F16>F14,F16,0)	
19 =((G18+H18)/118)*100	
20 =F18*F9	
21	
22 =+(F18*(LN(F8/\$B\$21))^2)	=+(G18*(LN(G8/\$B\$21))^2)
23	
24 =F5*F9	=C5*C9
25	
26 =+(F5*(LN(F8/\$B\$25))^2)	=+(G5*(LN(G8/\$B\$25))^2)
22	
28	5
29 SAMPLE	COUNT
30 31-Jan	11-Feb
31	
32	
CALCULATIONS DESCRIBED IN THE	
35 PROCEDURE	
37	
38	

1 1 1 3 103 F F 4 1047		H	
F 1.55 - 0.1 1.55 - 0.1 1.5	-		
1.55 - 0.1 1.55 - 0.1 SQRT[(H10/(H11*60)^(H13*60)^(1+(H13)H11)]))/(H12*H13*60)^1000 SQRT[(H10/(H11*60)))/H12)*1000 L3*60)-(H13*60))/(H12*H13*60)^1000 L3*60)-(H13*60)/(H13*60))/(H12*H13*60)^1000 H14,***,*N0* H14,****,*N0* M(H8/SBS21))*2) M(H8/SBS221))*2) M(H8/SBS221))*2) M(H8/SBS221))*2) M(H8/SBS221))*2) M(H8/SBS221))*2) M(H8/SBS221)*2) M(H8/SBS22)*2) M(H8/SBS22) M(H8/SBS22) M(H8/SBS22) M(H8/S	2		Σ
1.55 - 0.1 1.55 - 0.1 SQRT(H10/(H11*60))*(H13*60)*(14(H13/H11)))/(H12*H13*60)*1000 I.3*60,-(H10/(H11*60))/(H12)*1000 I.3*60,-(H10/(H11*60))/(H12)*1000 I.3*60,-(H10/(H11*60))/(H12)*1000 I.3*60,-(H10/(H11*60))/(H12)*1000 I.3*60,-(H10/(H11*60))/(H12)*1000 I.3*60,-(H10/(H11*60))/(H12)*1000 I.3*60,-(H10/(H11*60))/(H12*H13*60)+1000)/(H12*H13*60)+10000 I.3*60,-	e		
1.55 - 0.1 SQRT[H10[(H11*60]*[H13*60]*[1+[H13/H11])]]]([H12*H13*60]*1000 L13*60]-[H10]([H11*60])],[H12]*1000 H14,***,*NO") H14,***,*NO") H14,***,**NO") H14,***,********************************	4	10.47	
1.55 - 0.1 SQRT(H10/(H11*60)*(H13*60)*(1+(H13/H11)))/(H12*H13*60)*1000 SQRT(H10/(H11*60))/H12)*1000 H14,"","NO") H14,.II.0,0) H14,.II.0,0) H14,.II.0,0) M14,.II.5	5	=(H4-H3)	=B5+C5+D5+E5+F5+G5+H5
0.39 =_LN(H8) =_LN(H8) 37 90 0.315 90 0.315 90 0.315 90 =[15(H13+H14,",","NO"] =[F(H16>H	9		
0.39 =LN(H8) 37 30 000 0.315 200 =[3-3.25*SQRT(H10/(H11*60))*(H13*60)*(1+(H13/H11)))/(H12*H13*60)*1000 =[3-3.25*SQRT(H10/(H11*60))*(H13*60)*(1+(H13*H11))/(H12*H13*60)*1000 =[3-3.25*SQRT(H10/(H11*60))*(H13*60)*(1+(H13*60)*1000) =[3-3.25*SQRT(H10/(H11*60))*(H13*60)*(1+(H13*H13*60)*(1+(H13*60)*(H13*60)	2		
=LN(H8) 37 900 0.315 900 =(3-13.29"SGRT (H10/(H11*60)"(H13*60)"(H13*60)"(14(H13/H11)))/(H12"H13*60)"1000 =(3-13.29"SGRT (H10/(H11*60)))/H12"(H13*60)"1000 =(3-13.29"SGRT (H10/(H11*60)))/H12)*1000 =(H15/(H16*H14,"","NO") =(H15/(H16*H14,"","NO") =(H15/(H16*H14,"","NO") =(H16*(L10/(H16*B525))/2) =+(H18*(LN(H8/SB525))/2) =+(H18*(LN(H8*(H8*(H8*(H8*(H8*(H8*(H8*(H8*(H8*(H8*	00	0.39	
37 900 0315 200 =(3+3.29"SQRT(H10/(H11*60)^(H13*60)^(1+(H13/H11)))/(H12*H13*60)^{1000} =(All5/H1,***NO*) ==(All5/H1,***NO*) ==F(H16=H14,***NO*) ==F(H16=H14,***NO*) ==F(H16=H14,***NO*) ==F(H16=H14,***NO*) ==F(H16=H14,***NO*) ==F(H16=H14,***NO*) ==F(H16=H14,***NO*) ==F(H16=H14,***NO*) ==F(H16=H14,***NO*) ==F(H16=H14,***NO*) ==F(H16=H14,****NO*) ==F(H16=H14,****NO*) ==F(H16=H14,****NO*) ==F(H16=H14,****NO*) ==F(H16=H14,****NO*) ==F(H16=H14,*****NO*) ==F(H16=H14,*****NO*) ==F(H16=H14,*****NO*) ==F(H16=H14,************************************	6	=LN(H8)	
900 0.315 200 =(3-3.25°SCRT(H10/(H11*60)^(H13*60)^{(1+(H13/H11)))/(H12^{H13*60)^{1000}} =(TLIS/(H13*60)-(H10/(H11*60)))/H12)*1000 =(H15/(H16>H14,II1,6,0)) =F(H16>H14,II1,6,0) =H7+H9 =(H18^{(LN(H8/\$B\$21))^2) =+(H18^{(LN(H8/\$B\$21))^2}) =+(H18^{(LN(H8/\$B\$21))^2}) =H5+H9 =+(H5^{(LN(H8/\$B\$230))^2}) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2) =H5^{(H16)}(LN(H8/\$B\$230))^2)^2)	10	1 37	
0.315 200 =(3+3.29*SCRT[H10/(H11*60)*(H13*60)*(1+(H13/H11)))/(H12*H13*60)*1000 43 =((H15/H14,"","NO") =F[H16×H14,"","NO") =F[H16×H14,"","NO"] =F[H16×H14,",","NO"] =H7+H9 =(H16*(LN(H8)\$B\$21))^2) =+(H18*(LN(H8)\$B\$25))^2) =+(H18*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(LN(H8)\$B\$25))^2) =f(H16*(H10*(H11*60))^{11})^{11} (H10*(H10*(H10*(H10*(H10*(H10*(H10*(H10*	1	000	
200 =(3+3.29°SCRT(H10(H11*60)*(H13*60)*(1+(H13/H11))))((H12*H13*60)*1000 +3 =((H15/(H13*60)-(H10/(H11*60)))/H12)*1000 =(F(H16*H14,"","NO") =F(H16*H14,H16,0) 0 =(F(H16*H14,H16,0) 0 =(F(H16*H14,H16,0) =(F(H16*H14,H16,0) =(F(H16*H14,H16,0) =(F(H16*H14,","NO") =(F(H16*H14,",","NO") =(F(H16*H14,","NO") =(F(H16*H14,",","NO") =(F(H16*H14,","NO") =(F(H16*H14,","NO") =(F(H16*H14,","NO") =(F(H16*H14,","NO") =(F(H16*H14,","NO") =(F(H16*H14,","NO") =(F(H16*H14,","NO") =(F(H16*H14,","NO") =(F(H16*H14,","NO") =(F(H16*H14,","NO") =(F(H16*H14,","NO") =(F(H16*H14,"	12	0.315	
=(H15((H11*60)*(H11*60)*(H13*60)*(1+(H13/H11)))/(H12*H13*60)*1000 =((H15((H13*60)-(H10((H11*60)))/H12)*1000 =F(H16>H14,H16,0) 0 =H18*H9 =+(H18*(LN(H8/\$B\$21))^2) =H(H8*(LN(H8/\$B\$21))^2) =H(H8*(LN(H8/\$B\$25))^2) =H(H8*(LN(H8/\$B\$25))^2) =H(H8*(LN(H8/\$B\$25))^2) =H(H8*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(LN(H8/\$B\$25))^2) =(H3*(H14*(H14)^2) + (H44*(H14)^2) + (H44*	15	1 200	
43 =(H15(H13*60)-(H10(H11*60)))/H12)*1000 =F(H16>H14,",",NO") =F(H16>H14,H16,0) 0 =H18*H9 =+(H8*(LN(H8i\$B\$21))^2) =+(H18*(LN(H8i\$B\$23))^2) =+(H18*(LN(H8i\$B\$23))^2) =+(H18*(LN(H8i\$B\$23))^2) To mBq/m3 F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/100) F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/1000) F3(18i(5D\$30*5E\$30/1000	14		
-((H15/(H13*60)-(H10/(H11*60)))/H12)*1000 =F(H15~H14," ","NO") =F(H16~H14," ","NO") 0 =H18*H9 =+(H18*(LN(H8/\$B\$21))^2) =+(H5*(LN(H8/\$B\$25))^2) =H5*H9 =+(H5*(LN(H8/\$B\$25))^2) =H5*H9 =+(H5*(LN(H8/\$B\$25))^2) =H18*H9 =+(H5*(LN(H8/\$B\$25))^2) =H18*H9 =+(H5*(LN(H8/\$B\$25))^2) =H18*H9 =+(H5*(LN(H8/\$B\$25))^2) =H18*H9 =+(H5*(LN(H8/\$B\$25))^2) =H18*H9 =+(H18*(SD\$30*\$5530/1000) =H18*H9 =+(H18*(SD\$30*\$5530/1000) =H18*H9 =+(H18*(SD\$30*\$5530/1000) =H18*H9 =+(H18*(SD\$30*\$5530/1000) =H18*H9 =+(H18*(SD\$30*\$5530/1000) =H18*H9 =+(H18*(SD\$30*\$5530/1000) =H18*H9 =+(H18*(SD\$30*\$5530/1000) =+(H18*(SD\$30*\$50)(H18*(SD\$30*\$50)(H18*(SD\$30)(H18*(SD\$30)(H18*(SD\$30)(H18*(SD\$30)(H18*(SD\$30)(H18*(SD\$30)(H18*(SD\$30)(H18*(SD\$30)(H18*(SD\$30)(H18*(S	15	: 43	
=F(H16>H14, ", "NO") =F(H16>H14, II, 6, 0) 0 =H18*H9 =+(H18*(LN(H8/\$B\$21))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) for mBq/m3 Tot mBq/m3 Fist18((\$D\$30^\$E\$30/1000) Fist18((\$D\$30^\$E\$30/1000) Fist18((\$D\$30^\$E\$30/1000) Fist18((\$D\$30^\$E\$30/1000) Fist18((\$D\$30^\$E\$30/1000) Fist18((\$D\$30^\$E\$30/1000) Fist18((\$D\$30^\$E\$30/1000) Fist18((\$D\$30^\$E\$30/1000) Fist18((\$D\$30^\$E\$30/1000)	16	=((H15/(H13*60)-(H10/(H11*60)))/H12)*1000	
=F(HI6>H1,H16,0) 0 =H18*H9 =+(H18"(LN(H8/\$B\$21))^2) =+(H5"(LN(H8/\$B\$25))^2)	17	==F(H16>H14," ","NO")	
0 =H18*H9 =+(H18*(LN(H8/\$B\$21))^2) =H5*H9 =+(H5*(LN(H8/\$B\$25))^2)	100	=IF(H16>H14.H16.0)	=(B18+C18+D18+E18+F18+G18+H18)
=H18*H9 =+(H18*(LN(H8/\$B\$21))^2) =H5*H9 =+(H5*(LN(H8/\$B\$25))^2)	19		
=+(H18*(LN(H8/\$B\$21))^2) =H5*H9 =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) To the	20	=H18*H9	=B20+C20+D20+E20+F20+G20+H20
=+(H18*(LN(H8/\$B\$25))^2) =H5*H9 =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H5*(LN(H8/\$B\$25))^2) =+(H18*(LN(H8/\$B\$25))^2)=+(H18*(LN(H8/\$B\$25))^2) =+(H18*(LN(H8/\$B\$25))^2)=+(H18*(LN(H8*(B*20)))=+(H18*(LN(H8*(H8*(H8*(LN(H8*(H8*(H8*(H8*(H8*(H8*(H8*(H8*(H8*(H8*	21		
=H5*H9 =+(H5*(LN(H8/\$B\$25))^2) Tot mBq/m3 Fsist8/(\$D\$30*\$E\$30/1000) Fsist8/(\$D\$30*\$E\$30/1000) Fsist8/(\$D\$30*\$E\$30/1000) Fsist8/(\$D\$20*SE\$30/1000)	22	=+(H18*(LN(H8/\$B\$21))^2)	=SUM(B22:H22)
=H5+H9 =+(H5*(LN(H8/\$B\$25))^2) Tot mBq/m3 Esistal((SD\$30*\$E\$30/1000) Esistal((SD\$30*\$E\$30/1000) Esistal(SD\$30*\$E\$30/1000) Esistal(SD\$30*\$E\$30/1000)	23		
=+(H5*(LN(H8/\$B\$25))^2) Tot mBq/m3 =\$1\$18i(\$D\$30^*\$E\$30/1000) E\$18i(\$D\$30^*\$E\$30/1000) CALCULATIONS DESCRIBED IN THE PROCEDURE	24	=H5*H9	=B24+C24+D24+E24+F24+G24+H24
=+(H5*(LN(H8/\$B\$25))^2) Tot mBq/m3 Fsis18/(\$D\$30*\$E\$30/1000) Fsis18/(\$D\$30*\$E\$30/1000) Fsis18/(\$D\$30*\$E\$30/1000) Fsis18/(\$D\$30*\$E\$30/1000)	25		
Tot mBq/m3 Fsis18/(\$D\$30"\$E\$30/1000) CALCULATIONS DESCRIBED IN THE PROCEDURE	26	s =+(H5*(LN(H8/\$B\$25))^2)	=B26+C26+D26+E26+F26+G26+H26
Tot mBq/m3 =sis18/(sDs30"sEs30/1000) CALCULATIONS DESCRIBED IN THE PROCEDURE	27		
Tot mBq/m3 Esis18i(sD\$30*\$E\$30/1000) CALCULATIONS DESCRIBED IN THE PROCEDURE	28		
Feis18/(\$D\$30"\$E\$30/1000) CALCULATIONS DESCRIBED IN THE PROCEDURE	29	Tot mBq/m3	Tot mg/m3
	30	=\$I\$18/(\$D\$30*\$E\$30/1000)	=\$!\$5/(\$D\$30*\$E\$30/1000)
	31		
	32		
	33		
PROCE	34		
FROCE	35	CALCUL	
3/	36	FROCE	
	3		

Figure B.5.: Spreadsheet calculations for Stage: F & Sum of all stages .

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