Malé Declaration 1ST emissions inventory workshop

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Part 2 –

The basics of emission inventory compilation

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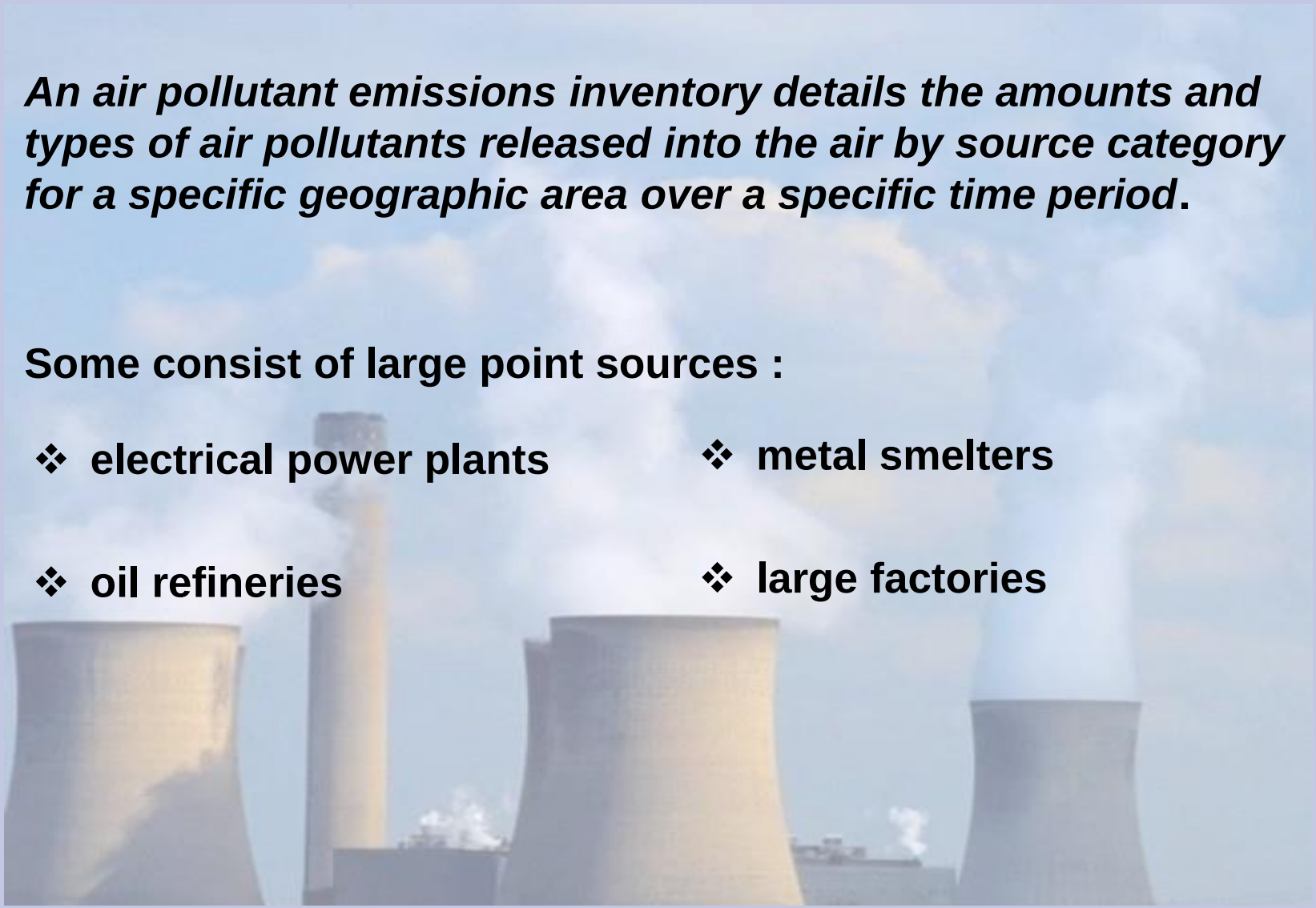
Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia

What is an emissions inventory?

***An air pollutant emissions inventory details the amounts and types of air pollutants released into the air by source category for a specific geographic area over a specific time period*.**

Some consist of large point sources :

- **electrical power plants**
- **oil refineries**
- **metal smelters**
- **large factories**



What is an emissions inventory?

Other source categories are made up of many small, or diffuse (area or line) sources:

- **domestic households**
- **small factories**
- **offices and public buildings**
- **cars and mobile sources**
- **vegetation fires (e.g. savanna burning)**
- **crop residue burning**
- **application of fertilizers**

What is an emissions inventory?

Sometimes *natural* emissions are also inventoried:

- **trees and other vegetation (VOCs & NH_3)**
- **Volcanoes (SO_2 & PM)**
- **Wind-blown dust from desert and disturbed areas**

But for the Malé Declaration inventories, we will only be concerned with *anthropogenic* (man-made) emissions.

The air pollutants to be inventoried using the Malé Declaration emission inventory manual

- **Sulphur dioxide (SO_2)**
- **Nitrogen oxides (NO_X)** comprises sum of NO and NO_2 but expressed as NO_2
- **Particulate matter (PM_{10} and $PM_{2.5}$)** particulate matter with diameters less than 10 or 2.5 microns (µm) respectively
- **Ammonia (NH_3)**

Other ozone (O_3) precursors (in addition to NO_X, SO_2 and NH_3):

- **Carbon monoxide (CO)**
- **Non-methane volatile organic compounds (NMVOCs)**

Top-down or bottom up approach?

- Depends on data availability – flexibility crucial
- If national data only – then top-down
- If large point source (LPS) data – bottom-up
- National and LPS sources can be inventoried together – the workbook will automatically adjust national activity data to avoid ‘double-counting’.

General Steps in Inventory Development

- Planning
- Data collection
- Calculations
- References/Documentation
- Quality assurance and quality control (QA/QC) throughout

General Steps in Inventory development

Planning:

- who has overall responsible and who is in the compilation team?
- which geographic area is to be covered (province, country, region)?
- which pollutants will be included?
- which emission source categories will be included?
- what time period or year will the inventory cover?
- what emission control strategies and technologies are in place?
- to whom will the results be communicated and by when?

General Steps in Inventory Development

Data collection:

- Source of activity data (international, national statistical office)?

- Source of fuel quality data e.g. NCV, S-content, ash content of coal (IEA, national sources)?

- Source of emission factors (defaults, national, regional)?

- Source of LPS data (questionnaires, surveys, industry bodies, site visits)?

General Steps in Inventory Development

Calculations:

- calculations are performed automatically by the Malé Declaration inventory workbook after activity data, emission factors and other data (fuel characteristics NCV, S-content, % ash of coal) have been entered into the workbook.

- workbook is transparent, calculations are shown, check them and *please* let someone know if you think you have found an error!

General Steps in Inventory Development

References/Documentation:

Compilation of the inventory into a final written report which should:

- accurately reflect the inventory effort
- ensure reproducibility of the inventory estimates
- enable an inventory user or reviewer to assess the quality of the emission estimates and identify all the data references
- provide a good foundation for future inventories
- support QA/QC assessments of the inventory

General Steps in Inventory Development

Quality assurance and quality control (QA/QC):

- *Quality Assurance (QA)*: external review and audit procedures by a third party (e.g. experienced emissions colleagues from other Malé Declaration countries)

- *Quality Control (QC):* accuracy checks (e.g. use of correct units), reality check (do totals make sense?), completeness checks (where are the gaps and how will they filled?), double counting (has a source been included under two different categories?)

General approach for calculation of emissions

Unless measured directly, emission are generally estimated as:

Emission = (emission factor) x (activity rate)

In practice the calculations are more complicated but the principle remains the same.

General approach for calculation of emissions

Emission = (emission factor) x (activity rate)

Emission factors are the rate of emission of a pollutant per unit of activity

Examples:

- **In power stations - kg NO_X per tonne coal burnt**
- **In copper smelters - kg SO_2 per tonne blister copper produced**

General approach for calculation of emissions

Emission = (emission factor) x (activity rate)

Examples of activity rates:

- **For *fuel combustion* - the annual rate of consumption of a fuel (e.g. kilotonnes coal burnt per year in power stations)**
- **For *industrial process emissions* - the annual rate of production of the commodity (e.g. kilotonnes copper blister produced per year at copper smelters)**

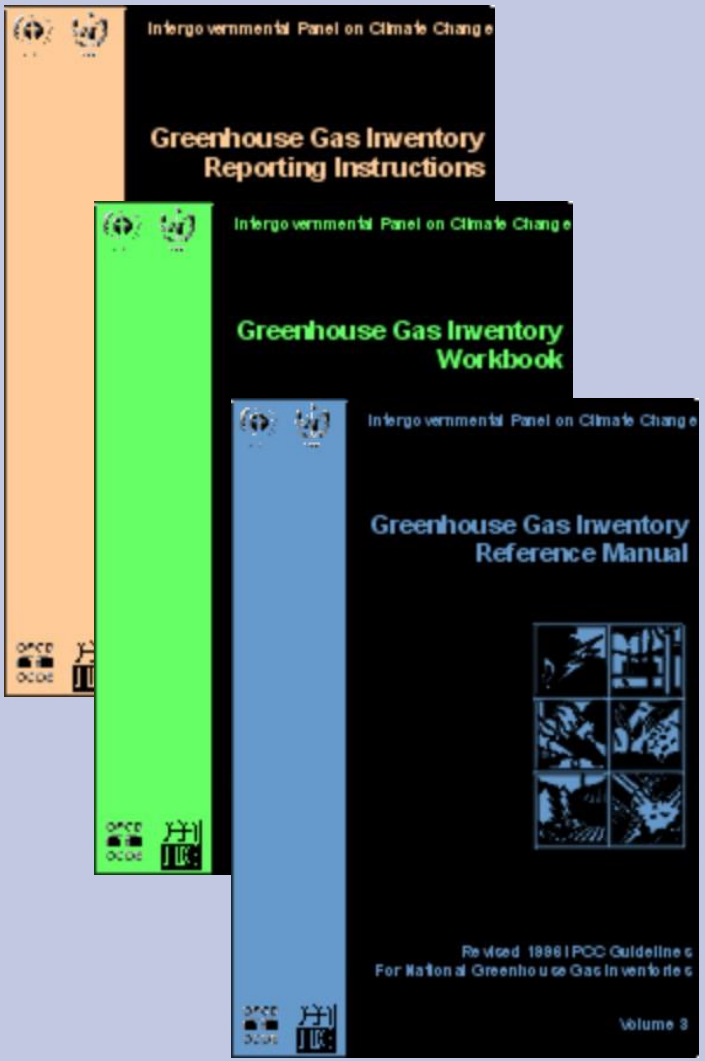
Emission Factors (EFs) used in the manual

Currently, the default EFs in the Malé Manual are mostly from European and North American source documents although where possible, EFs specific to developing country regions, especially Asia, are suggested:

- **Some fuel combustion EFs for SO_2 and NOx from Kato and Akimoto (1992) (Asian emissions inventory)**
- **CO and PM emissions from household stoves in India**
- **NOx emissions from household stoves in China**
- **NOx, CO, NMVOC and NH_3 emissions from earthen charcoal kilns in Zambia**
- **Emissions of all pollutants from Indian road vehicles (detailed method)**
- **In agriculture, NH_3 emissions from manure management and fertilizer use**

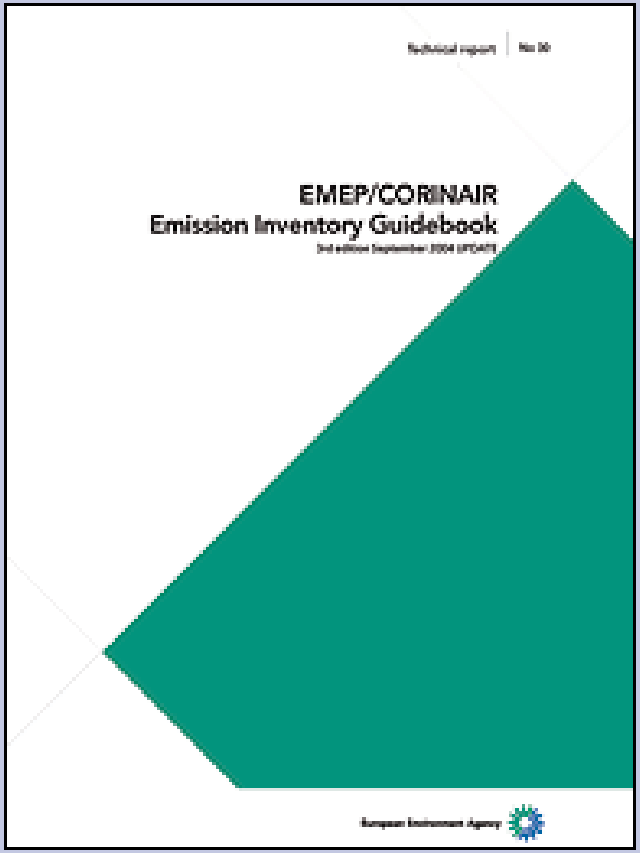
International/regional approaches:

Global - the Intergovernmental Panel on Climate Change (IPPC)



- 1996 IPCC Guidelines for National Greenhouse Gas Inventories
- intended to ensure that all reports are *consistent* and *comparable*
- software for the Workbook also available (Microsoft Excel)
- *but* mainly CO_2 and other direct GHGs plus indirect GHGs (e.g. NO_x, SO_2, CO and NMVOCs) - does *not* include ammonia (NH_3) or particulate matter (PM)

International/Regional approaches:
In Europe – the EMEP/Corinair Atmospheric Emission Inventory Guidebook



- intended to provide a *complete, consistent and transparent* air pollutant emission inventory for Europe
- can be used for national, regional or local emission inventories
- very useful resource for emission inventory compilers, *but*
- no dedicated software available to accompany it

International/Regional approaches:

In North America - The (US)EPA's Compilation of Air Pollutant Emission Factors (AP-42)

- methodologies for estimating emissions presented in the form of *Emission Factors*
- various associated software tools available but no standard inventory preparation spreadsheet tool
- very useful resource – most EFs used elsewhere come from AP-42

RAPIDC
Regional Air Pollution in Developing Countries

SEI STOCKHOLM ENVIRONMENT INSTITUTE

Malé Declaration on Control and Prevention of Air Pollution
and Its Likely Transboundary Effects for South Asia

The Malé Declaration Air Pollutant Emissions Inventory Manual

Draft Version 2.1
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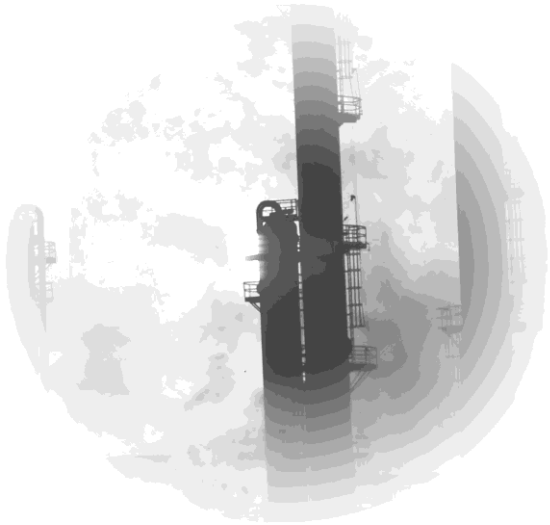

UNEP
RRC-AP

SACEP

SEI

Summary of emission source categories used in the manual

Energy sources:

1 Combustion in the Energy Industries
2 Combustion in Manufacturing Industries and Construction
3 Transport
4 Combustion in Other Sectors
5 Fugitive emissions from fuels

Other source sectors:

6 Industrial Processes
7 Solvent and Other Product Use
8 Agriculture
9 Vegetation Fires & Forestry
10 Waste
11 Natural sources

Data required to compile an emissions inventory

International sources of activity data:

- ***Fuel consumption -*** International Energy Agency (IEA) Energy Statistics and Balances – data up to 2002 available on CD-ROM **but Bhutan and Maldives** are not covered
- ***Industrial processes -*** Annual production by country in: United Nations Industrial Commodity Statistics Yearbooks and, for metals, minerals and fossil fuels, the United States Geological Survey (USGS)
- ***Agricultural activity –*** Food and Agriculture Organisation's (FAO) on-line database FOASTAT

Data required to compile an emissions inventory

Regional and national sources of data from government departments, industry, research institutes, research publications, e.g.:

- **Areas of different natural vegetation types burnt in the relevant year**
- **Average levels of emission control in the various industrial sectors (e.g. sulphur recovery in copper smelters, SO_2 and NO_x controls on power stations)**
- **Point source emissions data for large facilities – if obtainable**

Units and conversions

Positive numeric superscripts indicate a '*raising to the power* of the preceding number, that is, *multiplying* the previous number by itself the number of time shown by the superscript :

10^{6} = 10 x 10 x 10 x 10 x 10 x 10 = 1,000,000 (i.e. a million)

Beware: in French 'milliers' means thousands not millions!

Negative numeric superscripts indicate 1 divided by the positive equivalent:

10^{-2} = $1/(10^2)$ = 1/(10 x 10) = 1/100 = 0.01 (i.e. one-hundredth)

10^{-3} = $1/(10^3)$ = 1/1000 = 0.001 (i.e. one-thousandth)

For units, negative superscripts can also be used instead of the solidus or forward slash (/) to mean 'per':

kilogrammes per kilojoule can be shown as **kg kJ^{-1}** or **kg/kJ**

grams per cubic metre can be shown as **g m^{-3} or g/m^3**

Units and conversions

The International System of Units (SI system) generally used in the manual:

- **SI basic unit of mass is the gram (g)**
- **SI basic unit of energy is the joule (J)**
- **SI basic unit of length is the metre (m)**
- **SI basic unit of time is the second (s)**
- **SI basic unit of power is the watt (W) [= 1 J/s]**

The following units are also recognised for use in the SI system

- **metric tonne (t) [= 1,000,000 g]**
- **kilogramme (kg) [=1,000 g]**
- **hectare (ha) [= 10,000 square metres (m^2)]**
- **minute (min) [= 60 s]**
- **hour (h) [= 3600 s]**
- **litre (L or sometimes l) [= 1,000 cm^3]**

Units and conversions

- Units of greater magnitude denoted thus:

Symbol	*Prefix*	*Multiple*	
P	peta	1,000,000,000,000,000	10^{15}
T	tera	1,000,000,000,000	10^{12}
G	giga	1,000,000,000	10^{9}
M	mega	1,000,000	10^{6}
k	kilo	1,000	10^{3}
h	hecto	100	10^{2}
c	centi	0.01	10^{-2}
m	milli	0.001	10^{-3}

Therefore one kilogram (kg) equals one thousand (10^3) grams, and one megagram (Mg) equals 10^6 grams.

Units and conversions

Note that the comma (,) is used to separate large numbers into multiples of a thousand (10^3) whereas the full stop (.) is used to indicate the decimal place.

Symbol	*Prefix*	*Multiple*	
P	peta	1,000,000,000,000,000	10^{15}
T	tera	1,000,000,000,000	10^{12}
G	giga	1,000,000,000	10^{9}
M	mega	1,000,000	10^{6}
k	kilo	1,000	10^{3}
h	hecto	100	10^{2}
c	centi	0.01	10^{-2}
m	milli	0.001	10^{-3}

Beware: In some countries the comma **(,)** may be used to indicate the decimal place but this is unusual and not the case in the Malé manual !

Units and conversions

Exceptions to use of SI units in the Malé manual:

- Fuel consumption activity data as reported by the International Energy Agency (IEA) Balances are expressed as **kilotonnes oil equivalent (ktoe)** where 1 toe = 10^7 kcal (kilocalories). The Malé workbook therefore allows for fuel consumption data to be input as ktoe (as well as in tonnes (t) or terajoules (TJ)).

- Similarly, Net Calorific Values (NCVs) for fuels given by the IEA are expressed as **tonnes oil equivalent per tonne (toe/t).** Therefore the Malé workbook is also set up to allow NCVs to be input in these units.

Units and conversions

In the Malé manual and workbook, emission rates and emission factors are expressed in terms of the weight of the pollutant 'species' concerned. Thus:

- **EFs for sulphur dioxide are expressed as kg SO_2 / tonne product (not kg S / tonne)**
- **For NOx, the EF would expressed in kg NOx (as NO_2) per tonne (not kg N / tonne)**

Units and conversions

Conversion factors for energy

To:	**TJ**	**Gcal**	**Mtoe**	**MBtu**	**GWh**
From:	multiply by:				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

Units and conversions

Conversion factors for mass

To:	**kg**	**t**	**lt**	**st**	**lb**
From:	multiply by:				
Kilogramme (kg)	1	0.001	9.84×10^{-4}	1.102×10^{-3}	2.2046
Tonne (t)	1000	1	0.984	1.1023	2204.6
Long ton (lt)	1016	1.016	1	1.120	2240.0
Short ton (st)	907.2	0.9072	0.893	1	2000.0
Pound (lb)	0.454	4.54×10^{-4}	4.46×10^{-4}	5.0×10^{-4}	1

Units and conversions

Exercise A:

1. 2,000 kg = …… t
2. 356,000 Mg = ……. kt
3. 65,000 mg = ……. kg
4. 10^6 g = …….. kg
5. 10^{12} m = …… km
6. 6 million tonnes = …… kt
7. 25,000,000 MJ = …… PJ
8. 0.0025 TJ = …… MJ
9. 10,000,000 m^2 = …… km^2
10. 0.250 Mtoe = …… ktoe

Units and conversions

Exercise B:

1. **1 ha = …… m^2**
2. **0.75 km^2 = …… ha**
3. **250 kg/kt = …… g/kg**
4. **50 g/kg = …….. %**
5. **45 t/TJ = …….. kg MJ^{-1}**
6. **150 ktoe = …… TJ** (Note: 1 Mtoe = 4.1868 x 10^4 TJ)
7. **150 toe t^{-1} = …….. TJ t^{-1}**
8. **80 g SO_2 /kg = …… kg SO_2 t^{-1}**
9. **50 g NMVOC per litre = …….kg NMVOC /hl** (Note: hl = hectolitre)
10. **2,000,000 m^3 /week = …….. x 10^6 m^3 yr^{-1}**

Exercise C

– practical session: getting to know the workbook

- Using an Excel spread sheet
- Structure of Malé emissions inventory preparation workbook:

  division into worksheets,

  navigation menus,

  freeze panes and scrolling in worksheets

  general data input areas (white),

  general data output areas (green),

  understanding the formulae used,

  final summary sheet

  recording tables for reference source(s) of activity data and emission factors if defaults not used (transparency of data)