HAWA USER GUIDE

Save as… > Save as text file (Ctrl + F)

The save as text file command would generate a text file named HAWAtext.txt consisting of the coordinates (x, y, and z in km) and concentration (μg/m^3) at those coordinates for 10 receptors. It also displays the location of the stacks (x, y, and z coordinates). The circular grid would also be saved in this text file as shown in HAWA (using the Calculate command). A sample of this text file is shown below.

	x(km)	y(km)	z(km)	concentration * 10^6, g/m3
Receptor 1	0.000000	0.100000	0.000000	104.678425
Receptor 2	0.000000	0.200000	0.000000	88.953104
Receptor 3	0.000000	0.300000	0.000000	61.072239
Receptor 4	0.000000	0.400000	0.000000	39.212134
Receptor 5	0.000000	0.500000	0.000000	26.364196
Receptor 6	0.000000	0.600000	0.000000	18.654824
Receptor 7	0.000000	0.700000	0.000000	13.781059
Receptor 8	0.000000	0.800000	0.000000	10.542458
Receptor 9	0.000000	0.900000	0.000000	8.296746
Receptor 10	0.000000	1.000000	0.000000	6.682996

Stack 1	0.000000	0.000000	0.000000
Stack 2	0.000000	0.000000	0.000000
Stack 3	0.000000	0.000000	0.000000
Stack 4	0.000000	0.000000	0.000000
Stack 5	0.000000	0.000000	0.000000
Stack 6	0.000000	0.000000	0.000000
Stack 7	0.000000	0.000000	0.000000
Stack 8	0.000000	0.000000	0.000000
Stack 9	0.000000	0.000000	0.000000
Stack 10	0.000000	0.000000	0.000000

x(km)	y(km)	z(km)	concentration * 10^6, g/m3
0.000081	0.100000	0.000000	104.677719
0.000163	0.200000	0.000000	88.952484
0.000244	0.300000	0.000000	61.071798
0.000326	0.400000	0.000000	39.211840
0.000407	0.500000	0.000000	26.363990
0.000489	0.600000	0.000000	18.654675
0.000570	0.700000	0.000000	13.780944
0.000652	0.800000	0.000000	10.542367
0.000733	0.900000	0.000000	8.296673
0.000815	1.000000	0.000000	6.682935
0.000896	1.100000	0.000000	5.488155

0.000978	1.200000	0.000000	4.580968
0.001059	1.300000	0.000000	3.877183
0.001141	1.400000	0.000000	3.321001
0.001222	1.500000	0.000000	2.874349
0.001304	1.599999	0.000000	2.510575
0.001385	1.699999	0.000000	2.210602
0.001466	1.799999	0.000000	1.960498
0.001548	1.899999	0.000000	1.749906
0.001629	1.999999	0.000000	1.571005

Note: It is important to change the name of this text file from HAWAtext.txt to another name to avoid HAWA from overwriting this file when the user uses the Save as text file command again in the same folder. This file would be generated in the same folder as where the HAWA file is saved.

Save as… > Save as Matlab .m file (Ctrl + M)

The save as Matlab .m file command would generate a .m file named HAWA.m consisting of a program that is written to run specifically for Matlab© so that Matlab© could plot a contour map. The X-Y grid is used mainly for this purpose, to generate the .m file. Please refer to Receptor Grid for more information on how to use the X-Y grid. The concentration generated would be in microgram per meter cube (μg/m^3) with the grid in kilometer (km). A sample of the program written is shown below.

```
x = [ -1.000000 -0.500000 0.000000 0.500000;

 -1.000000 -0.500000 0.000000 0.500000;

 -1.000000 -0.500000 0.000000 0.500000;

 -1.000000 -0.500000 0.000000 0.500000;

];

y = [ 0.000000 0.000000 0.000000 0.000000;

 0.500000 0.500000 0.500000 0.500000;

 1.000000 1.000000 1.000000 1.000000;

 1.500000 1.500000 1.500000 1.500000;

];

z = [ 0.000000 0.000000 0.000000 0.000000;

 0.000000 0.000000 4.923853 0.000000;
```

```
 0.000000 0.001999 1.843548 0.001963;

 0.000001 0.030519 0.975186 0.030038;

];

v = [0:1:300];

kontor = contour(x,y,z);

clabel(kontor,v);

maksz = 0;

for i = 1:4.000000

for j = 1:4.000000

if maksz < z(i,j)

maksz = z(i,j); maksx = x(i,j); maksy = y(i,j);

end

end

end
```

Open this file using Matlab©. Under the Debug menu, choose run (or press the key F5). If the file is not in Matlab© work folder then a window will pop up. Choose "Change Matlab current directory" and click OK. The contour graph will be displayed. It must be put into attention that Matlab© 6 was used to describe the above procedure.

Note: It is important to change the name of this .m file from HAWA.m to another name to avoid HAWA from overwriting this file when the user uses the Save as Matlab .m file command again in the same folder. This file would be generated in the same folder as where the HAWA file is saved.

Receptor > Receptor location

In the Receptor location window, the user can input up to 10 individual receptor locations. The user would have to specify the x, y, and z (height from sea level) coordinate for the number of receptor desired. The unit must be in kilometer (km).

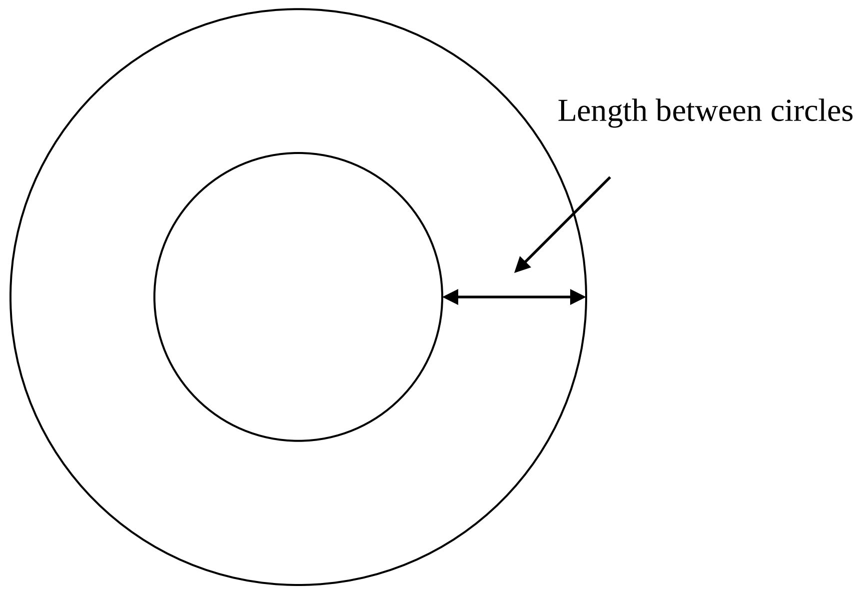
Receptor Grid > Grid

Circular grid

The circular grid can be displayed directly in HAWA or as text file.

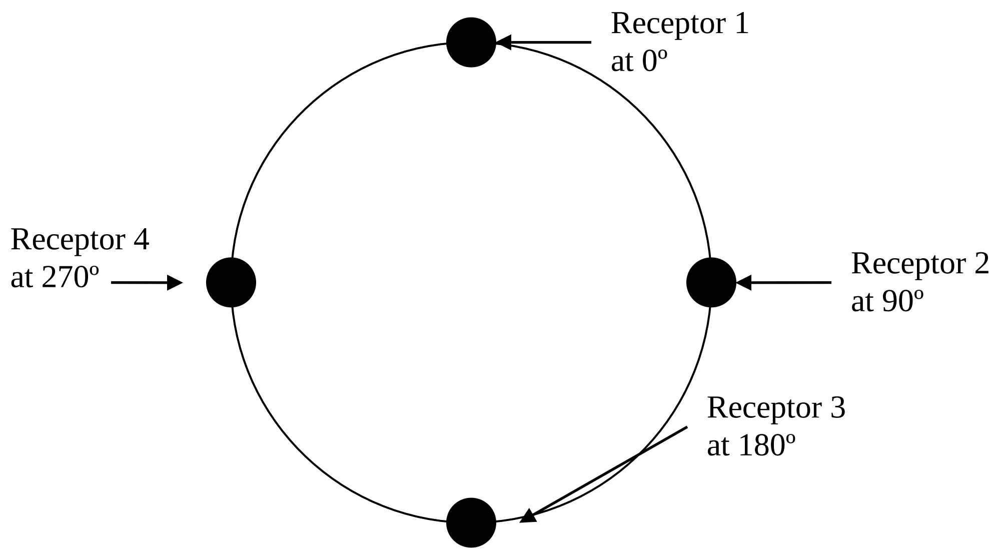
Length between circles

A circular grid is a grid that is circular in nature instead of the normal Cartesian grid which an array of squares. A circular grid requires the length in between each circle as shown in the following diagram. The unit must be in meter (m).



Amount of receptors in each circle

The amount of receptors in each circle is the amount of receptor point in a circle of a circular grid. The receptor is distributed evenly along the circle with equal length between each receptor. For example, if there are 4 receptors in a circle, then each receptor would be placed at 0º, 90º, 180º, and 270º respectively as shown in the following diagram.



Amount of circles

The amount of circles is the total number of circles to make a circular grid. For example, if the user specifies 4 receptors in each circle with the amount of circle are 5, then the total amount of receptors is 20.

Height from sea level

This is an equivalent to the z coordinate used in the Receptor window. Either circular or X-Y grid (Cartesian grid) can use this option. If the circular of Cartesian grid is on ground level (sea level), then this option would be set as zero. If the grid is at 200 m above ground level, then this option would be set as 0.2. The unit must be in kilometer (km).

X-Y grid (used in writing .m Matlab© file)

Unlike the circular grid, X-Y grid can only be use to generate an .m file (Matlab© file). This file can be loaded directly into Matlab© to draw a contour map of the air pollution dispersion.

Min X value

The minimum values of the x coordinate (horizontal) value of the grid. The unit must be in kilometer (km).

Max X value

The maximum values of the x coordinate (horizontal) value of the grid. The unit must be in kilometer (km).

Min Y value

The minimum values of the y coordinate (vertical) value of the grid. The unit must be in kilometer (km).

Max Y value

The maximum values of the y coordinate (vertical) value of the grid. The unit must be in kilometer (km).

Distance in between X and Y

The distance in between each x and y coordinate. For example, the distance between x coordinate 0.1 and x coordinate 0.2 is 0.1. The same goes for the y coordinates. The smaller the distance in between coordinates, the more refined the grid would be. The unit must be in kilometer (km).

As in the following diagram of a Cartesian grid, the minimum x value is 1 while the maximum x value is 4. The minimum y value is 5 while the maximum y value is 8. The distance between coordinates is 1. Notice that the distance between minimum and maximum value for both x and y axis has to be the same, in this example the distance is 4 for both x and y axis. In other words, the grid has to be a perfect square.

(1,8)			
(1,5)			(4,5)

Data > Environmental data

Urban (rural is default)

Urban or rural terrain changes the coefficients used in the equations of HAWA. This includes wind adjusted to height equation, dispersion parameter equations, and lateral and vertical virtual distance equations. So it is important for the user to determine the type of terrain the air dispersion modeling is being conducted.

According to method suggested by Irwin, there are 2 categories of procedures that can be used to determine urban or rural terrain. The first one is called land use procedure. If 50 % of the land is filled with industrial or domestic buildings, then enable the urban option. Otherwise, leave it blank to enable the rural option.

The second procedure is population density procedure. If the population density is more than 750 people/km^2, use the urban option.

The land procedure method is preferred because there are instances where population is low but building count is high. This usually occurs in highly industrialized areas.

Atmospheric pressure

Atmospheric pressure is the pressure of the atmosphere surrounding the source. The pressure must be in millibars (mb). Typical value of atmospheric pressure of Malaysia at ground level is 1000 mb (1 atm).

Ambient temperature

Ambient temperature is the temperature of the area surrounding the source. The temperature must be in Kelvin (K). Typical value of ambient temperature in Malaysia is 303 K (30 ºC) during the day and 298 K (25 ºC) at night.

Wind speed

Wind speed is the speed of wind in the area surrounding the source. The unit must be in m/s.

Note: The wind is not allowed to be less than 1 m/s. If the wind speed is less than 1 m/s then it is advisable for the user to assume the wind speed to be 1 m/s.

Wind direction

Wind direction is the direction of where the wind is coming from. South wind heading north is 0 rad. West wind heading east is 1.57 rad. North wind heading south is 3.142 rad. East wind heading west is 4.71 rad. The unit of the wind direction is in radian (rad).

Stack tip downwash

Stack-tip downwash occurs when the velocity of the stack is insufficient compared to the wind speed causing plume downwash at the stack exit. It is advisable to enable this option as it is a compulsory according to EPA modeling standards. EPA recommends not to use stack-tip downwash with building downwash and Schulman & Scire plume rise.

Averaging time

Instantaneous value of pollutant concentration is not feasible to predict, thus an averaging value of pollutant concentration at a given time is used. The user can opt to use the following equation (based on the work of Hino, 1968) built in HAWA relating 10 minute average pollutant concentration to averaging time chosen by the user (1 min to 300 min).

$$C_t = C_o \left(\frac{10}{t} \right)^p$$

Where,

C_o	=	concentration for 10 minute averaging time
C_t	=	concentration for averaging time t
t	=	averaging time, min
p	=	0.2 (averaging time less than 10 min) or 0.5 (averaging time more than 10 min)

The averaging time can also be based on input data. If hourly meteorological and emission data are used for 1 hour, then the averaging time is 1 hour. Averaging time can be increased by adding concentration value of each input of meteorological and emission data (every 10 min, every hour, etc.) divided by the amount of time data was used. It must be noted by the user that this operation must be done manually by the user in Matlab® or on paper.

For example,

1st hour	10 µg/m³
2nd hour	30 µg/m³
3rd hour	20 µg/m³
Total	60 µg/m³

Thus, the averaging time is

$$(60 / 3)\ \mu g/m^3 \quad = \quad 20\ \mu g/m^3$$

Note: Do not change the default setting of 10 minutes if the user intends to use the above method of averaging time.

Mixing height

Mixing height is the height of an inversion where the pollutants are not allowed to disperse vertically due to the temperature profile of the atmosphere. The inversion will act as a lid of the atmosphere, not allowing the pollutants to disperse through it. If the height of the inversion is below the effective plume height, then HAWA will automatically set the ground level concentration to zero because of the inability of the pollutants to breach the inversion to reach ground level. The unit of the mixing height is in meter (m).

One method of determining mixing height is using the Holzworth method. The method is as follows.

The Holzworth method provides twice-per-day (morning and afternoon) mixing heights based on calculations using routine NWS upper-air data. The morning mixing height is calculated as the height above ground at which the dry adiabatic extension of the morning minimum surface temperature plus 5 °C intersects the vertical temperature profile observed at 1200 Greenwich Mean Time (GMT). The minimum temperature is determined from the regular hourly airways reports from 0200 through 0600 Local Standard Time (LST). The "plus 5 °C " was intended to allow for the effects of the nocturnal and early morning urban heat island since NWS upper-air stations are generally located in rural or suburban surroundings. However, it can also be interpreted as a way to include the effects of some surface heating shortly after sunrise. Thus, the time of the urban morning mixing height coincides approximately with that of the typical diurnal maximum concentration of slow-reacting pollutants in many cities, occurring around the morning commuter rush hours.

The afternoon mixing height is calculated in the same way, except that the maximum surface temperature observed from 1200 through 1600 LST is used. Urban-rural differences of maximum surface temperature are assumed negligible. The typical time of the afternoon mixing height may be considered to coincide approximately with the usual mid-afternoon minimum concentration of slow-reacting urban pollutants.

Hourly mixing heights, for use in regulatory dispersion modeling, are interpolated from these twice per day estimates.

The other method would be to use the mechanical mixing height equation to estimate the lower mixing height limit during neutral and unstable conditions.

The equation is,

$$z_m = \frac{0.3u_*}{f}$$

Where,

u_*	=	friction velocity (m/s)
f	=	Coriolis parameter (e.g. 9.374×10^{-5} s^{-1} at 40º latitude)

Height wind is recorded

The height of the anemometer used to record wind speed is important to note. This is because wind speed changes at different height. The default value of this height is 10 m (because most anemometers are as high as 10 m). The unit of the height wind is recorded is in meter (m).

The equation where this height is used is as follows.

$$u_s = u_{ref}\left(\frac{h_s}{z_{ref}}\right)^p$$

Where,

u_s = wind speed adjusted to release height (m/s)
u_{ref} = wind speed measured at reference height (m/s)
h_s = physical stack height (m)
z_{ref} = height wind is recorded (m)
p = exponent (changes with stability class and urban/rural terrain)

Stability Category	Rural Exponent	Urban Exponent
A	0.07	0.15
B	0.07	0.15
C	0.10	0.20
D	0.15	0.25
E	0.35	0.30
F	0.55	0.30

The stack height wind speed, u_s, is not allowed to be less than 1.0 m/s.

Wet deposition, Precipitation rate

The rate of precipitation is used in HAWA to calculate the scavenging ratio. The scavenging ratio describes the characteristics of the pollutants (e.g. solubility and reactivity of pollutants, size distribution for particles) as well as the nature of the precipitation (e.g. liquid or frozen). The unit must be in millimeter per hour (mm/hr).

Stability class

Each stability class stands for the different letters from A to F.

Very unstable	=	A
Moderately unstable	=	B
Slightly unstable	=	C
Neutral	=	D
Slightly stable	=	E
Stable	=	F

The user is needed to choose the proper stability class following the criteria in the table below.

Surface wind speed, m/s	Day incoming solar radiation			Night cloudiness	
	Strong	Moderate	Slight	Cloudy(≥4/8)	Clear(≤3/8)
<2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Strong corresponds to clear summer day with sun higher than 60º above the horizon
Moderate corresponds to a summer day with a few broken clouds, or a clear day with sun 35º - 60º above the horizon
Slight corresponds to a fall afternoon, or a cloudy summer day, or clear summer day with the sun 15º - 35º

Note:
1. Regardless of wind speed, class D should be assumed for overcast conditions, day or night.
2. Cloudiness is defined as the fraction of sky covered by clouds.

Adapted from Cooper and Alley, 1994.

Stacks > Stack # data

Stack gas temperature

The temperature of the gas exhaust stream before exiting the stack. The unit must be in Kelvin (K).

Stack inner diameter

The inner diameter of the stack is also needed in the plume rise equation which is essential in air dispersion modeling. The unit must be in meter (m).

Stack gas velocity

The velocity of the gas exhaust stream before exiting the stack. The unit must be in meter per second (m/s).

Volumetric flowrate

Volumetric flowrate is the amount of exhaust gas is vented out into the atmosphere per second. The unit must be in grams per second (g/s).

Stack height

Stack height is the height of the stack, from the base until the tip of the stack. The unit must be in meter (m).

Half life of pollutant

The half life of the pollutant is used to account for pollutant removal by physical or chemical processes. This term is not use in the model unless the half life of the pollutant is specified. The unit must be in seconds (s).

Note: SO_2 has a half life of 4 hours (14400 s).

Wet deposition, Precipitation rate

The rate of precipitation is used in HAWA to calculate the scavenging ratio. The scavenging ratio describes the characteristics of the pollutants (e.g. solubility and reactivity of pollutants, size distribution for particles) as well as the nature of the precipitation (e.g. liquid or frozen). The unit must be in millimeter per hour (mm/hr).

Dry deposition

HAWA provides an option for the user to use dry deposition in the model. The user is then needed to specify the particle density (grams per centimeter cube or g/cm^3) and particle diameter (micrometer or µm). These are used to calculate the gravitational settling velocity (centimeter per second or cm/s). This means that the user can only specify one type of particle in a single run. Usually, particles that are more than 20 µm need to use this option because particles this size are heavier and disperse downwards to ground level more rapidly compared to gases. In many applications, dry deposition is not used to achieve a conservative estimate of the pollutant dispersion.

Plume rise, Buoyancy induced

Buoyancy induced dispersion is recommended by the EPA to be used in conjunction with any air dispersion modeling. Buoyancy induced dispersion accounts for the initial dispersion of the plume and turbulent entrainment of the air. EPA recommends not to use buoyancy-induced dispersion with building downwash and Schulman & Scire plume rise.

Plume rise, Briggs or Schulman and Scire

The user has a choice between choosing Briggs plume rise equations or Schulman and Scire plume rise equations. Schulman and Scire plume rise equations are typically used with the building downwash option. Briggs plume rise equations are used in other applications not involving building downwash.

Location of stack, Coordinate-X, Coordinate-Y, Coordinate-Z

The stack location on a Cartesian grid is needed to be specified by the user. This includes the x and y coordinates in kilometers (km). The z coordinate means the elevation of the stack above sea level in kilometers (km). At sea level, the z coordinate is zero.

Building downwash, Building downwash, Building location

If a building lies directly in the path of the plume, then the building downwash option is needed to be enabled. The maximum distance of the building from the stack would be not more than 0.8 km. Building location means whether the plume impacts the building at the edge of the building, if not then the option must be disabled. Only one building for each run, so choose a building which is the biggest thus has the most impact to the plume.

A building would cause wake effects when the distance between the stacks and the nearest part of the building is less than or equal to 5 times the lesser of the height or width of the building. A building is assumed to cause wake effects if the stack is located in the rectangle shown in figure.

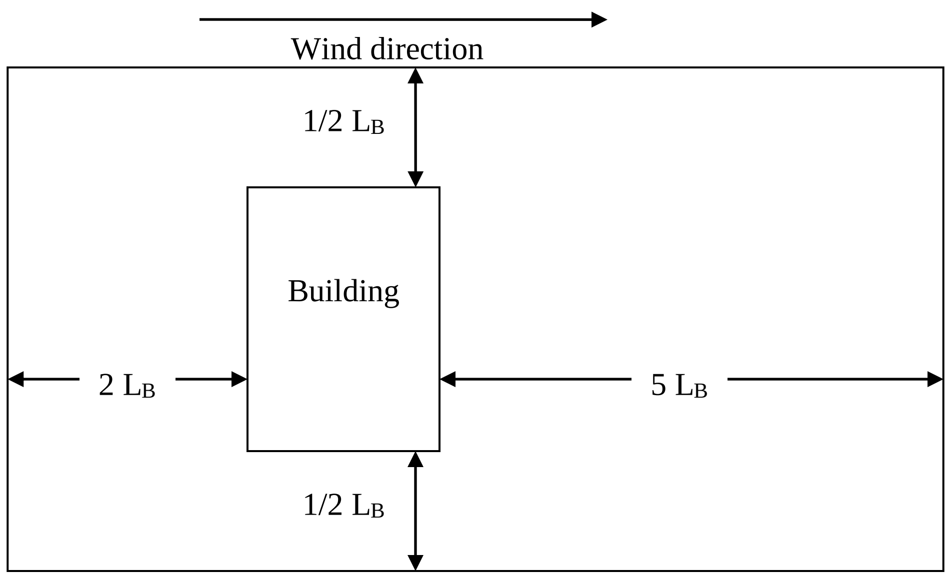


Figure 1

Note: L_B is the lesser of building height or width

Building height

If the building is of different heights, take the tallest height perpendicular to the path of the plume. The unit must be in meter (m).

Building width

If the building is of different widths, take the bigger width perpendicular to the path of the plume. The unit must be in meter (m).

Calculate (Ctrl + L)

This command allows the user to display the concentration at 10 different receptor points along with the concentration of pollutants using the circular grid. Displaying this information may be slow with higher amount of receptor points.

Draw graph > Draw bar graph (Ctrl + B)

This command allows the user to draw a bar graph of the concentration of the 10 individual receptors. The concentration is in microgram per meter cube ($\mu g/m^3$).

Draw graph > Draw pie chart (Ctrl + G)

This command allows the user to draw a pie chart of the contribution of pollutants from individual stack on receptor 1. The unit is in percentage (%).

Draw graph > Draw time-dependent graph (Ctrl + T)

This command allows the user to draw a time-dependent graph of the concentration at receptor 1 from 0 min up to 300 min (5 hours) for every 15 minutes. It uses the Hino equation and factors explained in Averaging time. The concentration is in microgram per meter cube ($\mu g/m^3$).