Stack height according to TA Luft
(Technical Instructions on Air Quality Control)

BESMIN

Program documentation of Version 1.3.0

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General remarks

Proper use of the program requires expertise in the context of the TA Luft (German Regulation *Technische Anleitung zur Reinhaltung der Luft*, Technical Instruction on Air Quality Control, which regulates uniform federal principles in Germany for the determination of air pollutants for installations requiring approval). The program and data are provided free of charge under the GNU Public License. No guarantee is given for their accuracy or suitability for a particular purpose. The entire risk associated with their use lies with the user.

The program is available on the website of the German Federal Environment Agency. Updates and information on problems are also posted here as needed. Questions regarding the program can be sent to the email address info@austal.de.

> *Note: Only the original version of* `Besmin.jar` *as provided by the German Federal Environment Agency should be used. Version 1.3.0 has the CRC32 checksum 9D426E9A. Version number and checksum are displayed in the header of the program window and in all text output.*

Contents

Update information

1.3.0 (9D426E9A)

- The program has been internationalised; German (identifier `de`) and English (`en`) are implemented by default. For details, see Section 3.
- For output (user interface, result file, screen output), a comma is used as the decimal separator for German and a point for all other languages.
- The CRC32 checksum of the program (file `Besmin.jar`) is displayed.
- The effective source height is consistently denoted by `heff` (previously also `he`).

1 Program

1.1 Background

TA Luft (2021) specifies a procedure for calculating the stack height in Section 5.5.2.2. The program Besmin (*Bestimmung der minimalen Schornsteinhöhe*, determination of the minimum stack height) can be used to perform this calculation for a single stack.

The specifications in Section 5.5 of the TA Luft alone already enable a programmatically implementation of the prescribed calculation method. With Besmin, the German Federal Environment Agency provides a public reference solution. It can be used both for practical applications and for checking other programs that claim to implement the calculation method according to Section 5.5 of the TA Luft.

1.2 Files

The calculation of stack height is based on a library of individual plumes that have been calculated in accordance with Annex 2, Section 14 of the TA Luft. For efficiency reasons, Besmin does not access the individual plumes directly, but rather uses an evaluation in which the scaled maximum concentration is noted for each plume. The directory containing the tables of maximum concentrations is named `maxima`. It is required to perform the calculation. The program checks whether the content corresponds to the original, so no changes must be made to the files.

The program Besmin is a JAVA program and requires a Java Runtime Environment (JRE) including JavaFX. The program has been tested under JAVA 21. For Windows 64-bit and Linux 64-bit, a local JRE tailored to Besmin is supplied (subdirectory `jre`). It is based on OpenJDK 21 Temurin (adoptium.net) and OpenJFX 21 Gluon (gluonhq.com). The JAVA program itself is named `Besmin.jar` and is located in the subdirectory `jar`. The JAVA program also expects the directory `maxima` to be located in the same directory as itself.

The directory above `jar` contains the program `Besmin.exe` for Windows 64-bit (and the program `Besmin` for Linux 64-bit), which starts `Besmin.jar` with the supplied local JRE. It can be started with a double click and executes the following command:

```
jre\bin\javaw -jar jar\Besmin.jar
```

Besmin applies the program PLURIS according to the standard VDI 3782-3 (2022), *Determination of plume rise*, for the calculation of plume rise. It is integrated in the

program Besmin (IBJpluris).

The current program versions are Besmin 1.3.0 and IBJpluris 3.2.0.

2 Method

The program Besmin determines the construction height[1] of an individual stack in such a way that, for every meteorological situation, the maximum value of the concentration near ground does not exceed the concentration specified by the S-value (numerical value in mg/m^3). This is based on the results of dispersion calculations that have been carried out for each of the meteorological situations to be considered[2] and a spectrum of effective source heights for a passive point source on flat terrain and without the influence of buildings.

The calculation is performed in two steps:

1. For each meteorological situation, the effective source height that must be reached such that the ground-level concentration does not exceed the S-value for the specified emission mass flow is calculated.

2. For each meteorological situation, the construction height is determined at which, together with the exhaust plume rise, the required effective source height is achieved.

The highest value of the construction heights determined for all meteorological situations is the stack height for a single stack in accordance with Section 5.5.2.2 of the TA Luft. If a plant has several stacks, compliance with the S-value in accordance with Section 5.5.2.2 of the TA Luft must be checked by superimposing the concentration plumes of the stacks. The program Besmax can be used for this purpose.

2.1 Work flow

The work flow is as follows:

1. The desired substance is selected from the drop-down list (the corresponding S-value is entered automatically). Alternatively, the substance *Unknown* is chosen and an S-value is explicitly entered in the input field.

2. The emission mass flow rate, the internal diameter of the stack, the exit tempera-

[1] The term construction height (*Bauhöhe*) has the same meaning in this program description as in Annex 2, Section 14 of the TA Luft. It is an intermediate result in determining the stack height according to Section 5.5.2 and is therefore not synonymous with the required construction height within the meaning of Section 5.5.2.1, Paragraph 8 of the TA Luft.

[2] Klug/Manier stability classes I to III/2 and wind speeds corresponding to a dispersion class statistics (*Ausbreitungsklassenstatistik*, AKS) of 1 to 12 m/s, a total of 25 situations.

ture, the exit velocity, and the water content[3] are entered in the corresponding fields[4]. As an alternative to exit velocity and water content, the norm volume flow (wet) and norm volume flow (dry) can be specified, both at operating conditions.

The program allows the following value ranges:

Symbol	Short name	Parameter	Unit	Value range
S	`sv`	S-value	mg/m^3	> 0
q	`eq`	emissions mass flow	kg/h	> 0
d	`dq`	inner diameter	m	$[0; 200]$
T	`tq`	exit temperature	°C	$[10; 600]$
v	`vq`	exit velocity	m/s	$[0; 50]$
x	`zq`	water content	kg/(kg dry)	$[0; 999]$
n_f	`nf`	norm volume flow (wet, at operation)	m^3/h	≥ 0
n_t	`nt`	norm volume flow (dry, at operation)	m^3/h	$\leq n_\mathrm{f}$
l	`lq`	liquid water content (informative only)	kg/kg	$[0; 0.04]$

The parameters `dq`, `tq`, `vq`, and `zq` (or `nf` and `nt`) are only required for calculating the plume rise. If the inner diameter `dq` or the exit velocity `vq` is zero, the calculation is performed without plume rise. In this case, stack height and effective source height are identical.

3. The calculation is started by pressing the button *Calculate stack height*. The button disappears and a coloured bar indicates the calculation progress.

If the norm volume flows are specified, the exit velocity is determined from the norm volume flow (wet) and the water content from the difference of the two norm volume flows, provided that no liquid water is present, see Section 4.1. The values that are not specified by the user, as well as the resulting liquid water content, are calculated immediately during input and updated in the corresponding fields.

In the case that the norm volume flows are specified, it is not the displayed rounded values of exit velocity and water content that are internally used for the stack height calculation, but rather the internally calculated exact values. Further details on the treatment of wet plumes are provided in a separate document in subdirectory `add`.

When entering numerical values, the program performs a check: If the entry cannot be interpreted as a numerical value, the background of the input field is coloured yellow. If the numerical value is not valid, the background is coloured red. A calculation can only be performed if no errors are detected.

When processing the individual meteorological situations, the calculated effective source height and the resulting construction height are listed in the tab *Intermediate results*. Once all meteorological situations have been processed, the line with the highest

[3] Mass of water vapour and liquid water per mass of dry air.

[4] The values are used as specified by the user and displayed again if necessary. Fixed decimal places are only used when `nf` and `nt` are calculated automatically from `vq` and `zq` and vice versa (2 for `vq`, 4 for `zq`, and 0 for `nf` and `nt`).

construction height is marked with an asterisk and the value is adopted.

The result is transferred together with the input parameters to the results list in the tab *Processed calculations*. If several calculations have been performed, a click on a line in the results list inserts the corresponding input data back into the input fields, and the corresponding intermediate results are also restored.

If the calculated construction height exceeds the maximum value of 250 m specified in the TA Luft, the value 999.9 m is displayed as an indication for this.

The results can be saved as a text file (UTF-8) by pressing the button *Save calculation results*. The file is saved in the directory `log`, which is located on the same level as the directory `jar` and is created if necessary. The name of the file is `besmin(`n`).log`, where n is a number used to distinguish between different result files and it is always incremented by 1.

2.2 Batch mode

The program Besmin can also be used without the graphical user interface. The call option `--help` (alternatively `-h` or `-?`) displays a short help text.

In batch mode, the source parameters and the S-value must be passed as command-line arguments. Each argument has the form `--`*shortname*`=`*value*. The short names to be used are listed in the table above (except for `lq`). At least the arguments `sv` and `eq` must be specified. The order of the arguments is arbitrary.

> *Note: Either v and x or n_f and n_t may be specified. If n_f and n_t are specified, the program checks whether the resulting liquid water content is zero and, if not, terminates with an error message.*

After the call

`Besmin --sv=`*value* `--eq=`*value* ...

or

`jre\bin\java -jar jar\Besmin.jar --sv=`*value* `--eq=`*value* ...

the progress is displayed, with one point for each call of IBJpluris. Finally, the source parameters and intermediate results are listed and the calculated stack height is displayed. The intermediate results contain the required effective source height `heff`, the statistical uncertainty of the concentration values used for its calculation (in brackets), and the required construction height `hb` for each stability class `kl` and each wind speed `ua`.

With the additional option `-i`, only the calculation of the exhaust gas parameters is performed (n_f and n_t from v and x or v and x from n_f and n_t) and the values are written to the log file. In this case, it is not necessary to specify the values `sv` and `eq`.

Examples:

```
jre\bin\java -jar jar\Besmin.jar --sv=1 --eq=100 --dq=1 --tq=40 --vq=10
```

```
jre\bin\java -jar jar\Besmin.jar --dq=1 --tq=40 --nt=30000 -i
```

3 Internationalisation

The program supports multiple languages (Native Language Support) and is delivered with German (code `de`) and English (code `en`) as default languages.

The language to be used is specified in the settings file `.besmin` (XML format) in the subdirectory `jar`. It can be changed with a text editor if necessary. This file is read when the program starts. In addition, the language can be specified with the command-line argument

`--language=`*ln*

where *ln* is the 2-letter language code. The argument overrides the settings file, but does not change it.

Example:

```
jre\bin\java -jar jar\Besmin.jar --sv=1 --eq=100 --language=en
```

In the graphical user interface, the contents of the settings file can be changed using a pop-up menu that appears by a right-click on the title at the top of the window. Changes will only take effect the next time the program is started and the settings file is read again.

4 Technical details

4.1 Calculation of source parameters

The norm volume flows (standard conditions at 273.15 K and 101300 Pa according to Section 2.4 of the TA Luft) are calculated from the given values of diameter d, exit temperature T (in degrees Celsius), exit velocity v, and water content x as

$$n_\mathrm{f} = \frac{\pi}{4} d^2 v \frac{T_0}{T_0 + T} \tag{1}$$

$$n_\mathrm{t} = \frac{n_\mathrm{f}}{1 + x(R_\mathrm{v}/R_\mathrm{d})} \tag{2}$$

with $T_0 = 273.15\,\mathrm{K}$, gas constant $R_\mathrm{d} = 287.05\,\mathrm{J/(kg\,K)}$, and $R_\mathrm{v} = 461.52\,\mathrm{J/(kg\,K)}$.

The calculation of exit velocity and water content from the specified norm volume flows is accordingly

$$v = \frac{4}{\pi} \frac{n_\mathrm{f}(T_0 + T)}{T_0 d^2} \tag{3}$$

$$x = \frac{n_\mathrm{f} - n_\mathrm{t}}{n_\mathrm{t}(R_\mathrm{v}/R_\mathrm{d})} \tag{4}$$

with $v = 0$ and $x = 0$ in case $d = 0$.

These conversions are only correct if there is no liquid water. Where Besmin shows a calculated numerical value for x, the calculation has been performed according to Equation (4), regardless of whether the result implies a liquid water content or not.

4.2 Internationalisation

Language-dependent text strings are located in the files `Besmin_`*ln*`.properties` (UTF-8) in the subdirectory `de/janicke/tal` within the JAR archive `Besmin.jar`.

If an additional language is to be added to the program, a properties file with the appropriate content and language identifier must be created and copied into this location in the JAR archive.

The new language can then be specified in the settings file `.besmin` or by the command-line argument `--language`. If the new language is also to appear in the pop-up menu of the user interface, the entry `bundles` must be expanded accordingly in all properties files.

Changing the contents of file `Besmin.jar` changes its CRC32 checksum.

4.3 Further information

Further technical details can be found in the *Report on Environmental Physics No. 9* (1st edition)[5]. In contrast to the explanations given there, the current version of Besmin allows construction heights down to 6 m in accordance with the specifications of the TA Luft.

In batch mode, the additional option `--log-pluris` can be used for testing purposes, in which case a log file containing information about the plume rise calculation is written out after the first internal call of IBJpluris.

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[5]The report is available as a PDF file from the German National Library (www.dnb.de) (urn:nbn:de:101:1-201709132627) and on the website of Janicke Consulting (www.janicke.de).