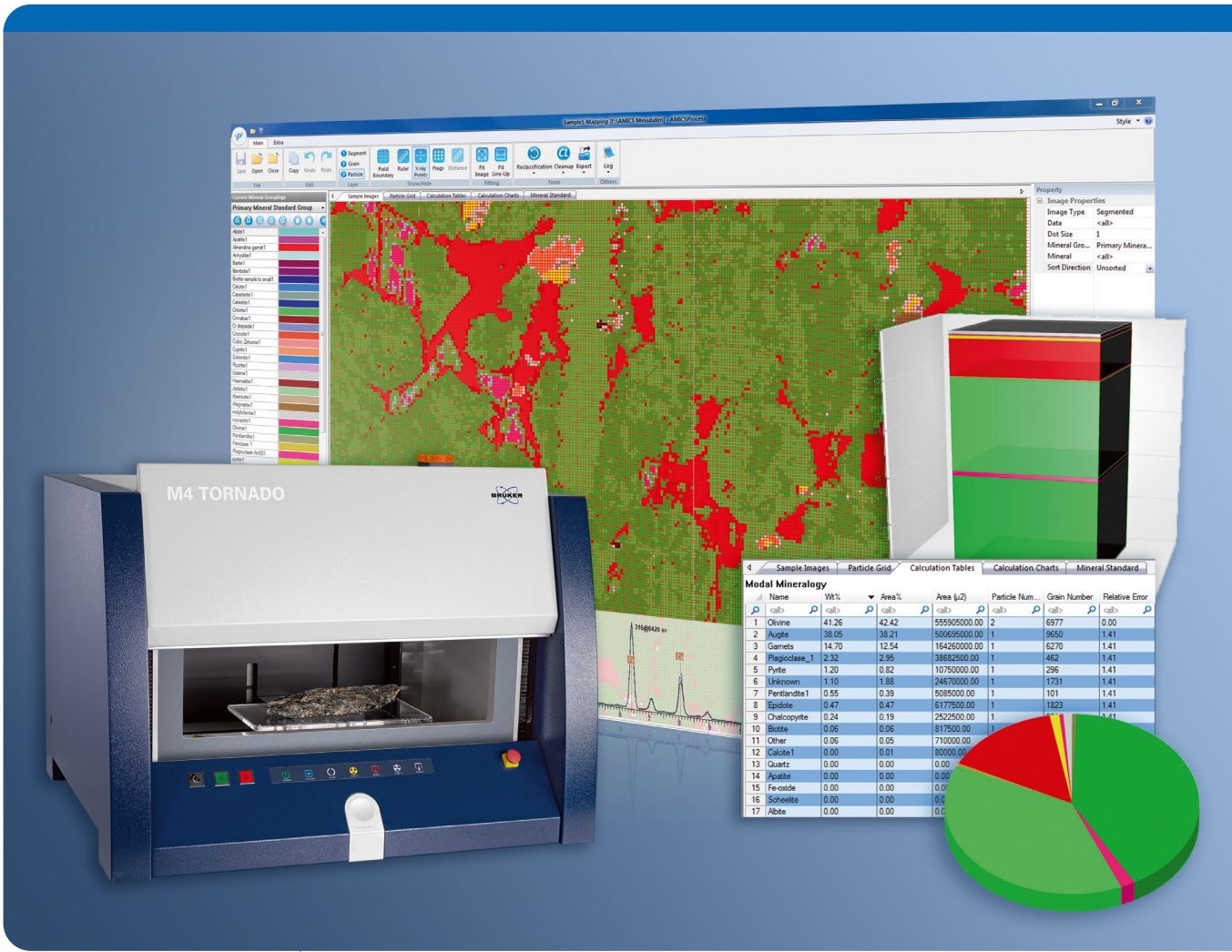


M4 TORNADO AMICS

- Automated Mineral Analyzer for Mining and Geosciences

Innovation with Integrity

Micro-XRF

The World's First Micro-XRF Mineral Analyzer

Micro-XRF is a highly sensitive and non-destructive elemental analysis method for diverse set of samples requiring little or no sample preparation. The M4 TORNADO^{AMICS} mineral analyzer tool brings together the ultra-fast high resolution elemental distribution analysis using Bruker's M4 TORNADO spectrometer and the powerful mineral identification and characterization software AMICS. This marriage creates the world's first benchtop Micro-XRF mineral analyzer.

Micro- XRF Mineral Analyzer

M4 TORNADO^{AMICS} is the world's first automated mineral analyzer based on X-ray fluorescence technology. It brings together the M4 TORNADO high performance Micro-XRF spectrometer and the AMICS (Advanced Mineral Identification and Characterization System) software suite.

Especially large geological samples, e.g. drill cores and hand samples as well as thin sections can easily be analyzed down to the micrometer scale making the M4 TORNADO^{AMICS} a powerful system in mining and geosciences. With its ability to measure unprepared samples at low to atmospheric pressure, it provides mineral phase results in the shortest time frames.

The AMICS software provides all the tools to determine modal mineralogy, mineral distribution and calculated assay of geological samples.

Your Benefits

- Combines centimeter scale mineral analysis with micrometer resolution
- Secure identification of mineral phases by X-ray analysis without the cost or complexity of an SEM
- No or little sample preparation meaning minimum time from sample to result
- Easy setup of measurements and automation of multiple samples
- Highly efficient data handling and reprocessing to optimize the workflow

Mineral Analysis with M4 TORNADO^{AMICS}

Automated Mineralogy

Analyzing drill cores, thin sections, fossils or geologically interesting samples has its challenges, especially to obtain the statistical and spatial distribution of minerals over larger sample areas in the centimeter range.

With a light microscope quick results can be acquired, but sample preparation and an experienced mineralogist is required then. Moreover, the mineral to be examined can not be determined certainly.

Alternatively, a scanning electron microscope (SEM) with an energy dispersive X-ray spectrometer (EDS) and some specialized software can be used to determine the mineralogy of the sample. However, SEM-EDS mineral analyzers are expensive to buy and maintain, and the sample has to be extensively prepared as well as carbon coated.

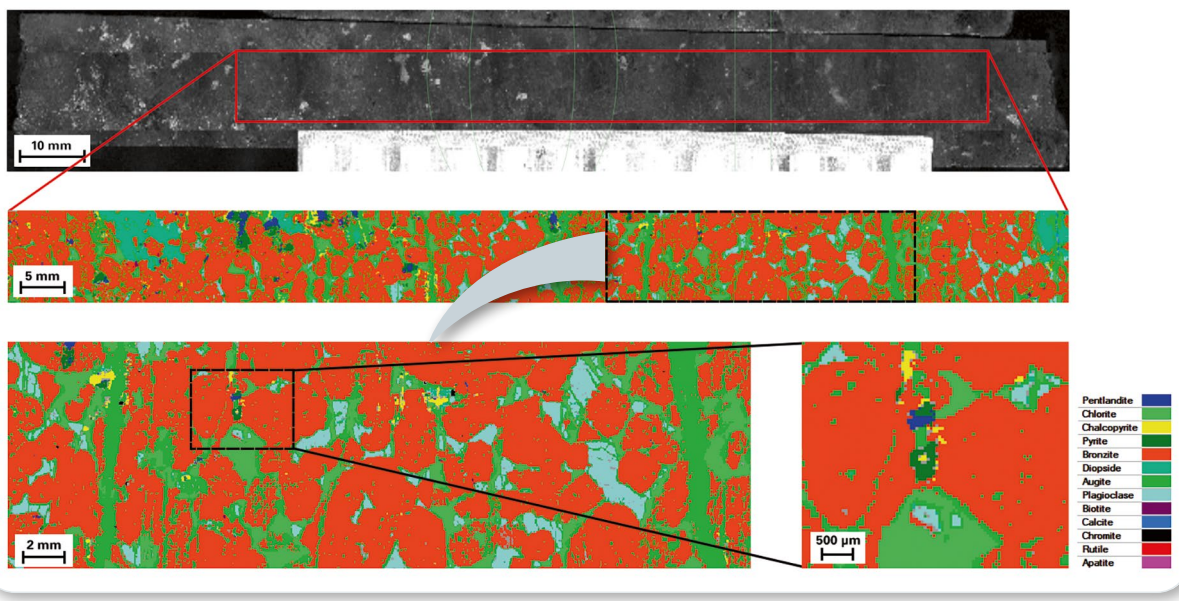
Sample preparation costs time and money, and once prepared for SEM-EDS analysis, it can take a day to measure more than a couple of square centimeters even with the fastest SEM-based mineral analyzers.

A new way to look at minerals

To overcome all these restrictions, there is a new option. M4 TORNADO^{AMICS} is a game changer employing the latest Micro-XRF (X-ray fluorescence) and software technology, that allows large samples to be analyzed quickly by measuring areas up to 190 mm x 160 mm with a high spatial resolution down to <20 µm and with little or no sample preparation.

In contrast to traditional quantification methods that would take hours, the innovative AMICS software technology can easily deal with large data sets, taking only minutes to reprocess sample files with over 500,000 pixels containing image, spectra, mineral identification data.

Large Drill Core Mineral Phase Map



This drill core was analyzed over an area of 11.05 x 117.85 mm² at a resolution of 50 µm per pixel with X-ray acquisition using a M4 Tornado 200 with Rh tube set to 50 kV at 300 µA, a dual 30 mm² XFlash® detector and 20 mbar sample chamber pressure. Mineral identification and characterization was completed in 13 hours and 20 minutes showing the classified minerals at every pixel. The zoomed images are extracted from the original map.

Quickly from sample to result

Sample preparation can be costly and time consuming. Nevertheless, it is often considered necessary in order to obtain good results. However, in some cases, e.g. fossils, it is not possible to prepare the sample. In other cases preparation may damage, distort or even disrupt the specimen. Apart from this, maintenance costs for the sample preparation equipment are also significant.

With M4 TORNADO^{AMICS} samples need no special preparation, e.g. a sample simply cut by saw or even a raw fossil can be easily analyzed as it is. A reasonably flat sample improves the spatial resolution and statistics but is not mandatory. The lack of sample preparation allows the sample to be placed into the sample chamber without delay.

Elements down to sodium can be analyzed with M4 TORNADO^{AMICS}. To optimize the detection conditions for light elements, the instrument possesses a vacuum system which can be adjusted to suit. A typical pressure setting is 20 mbar.

A major advantage working with the AMICS software is the simple setup for the sample analysis. Only a few steps must be followed to start a measurement: creation of an overview or mosaic image of the stage or selected sample taking a few seconds, interactive defining of sample and measurement areas by mouse click and drag, and finally checking that all desired samples and measurements are selected.

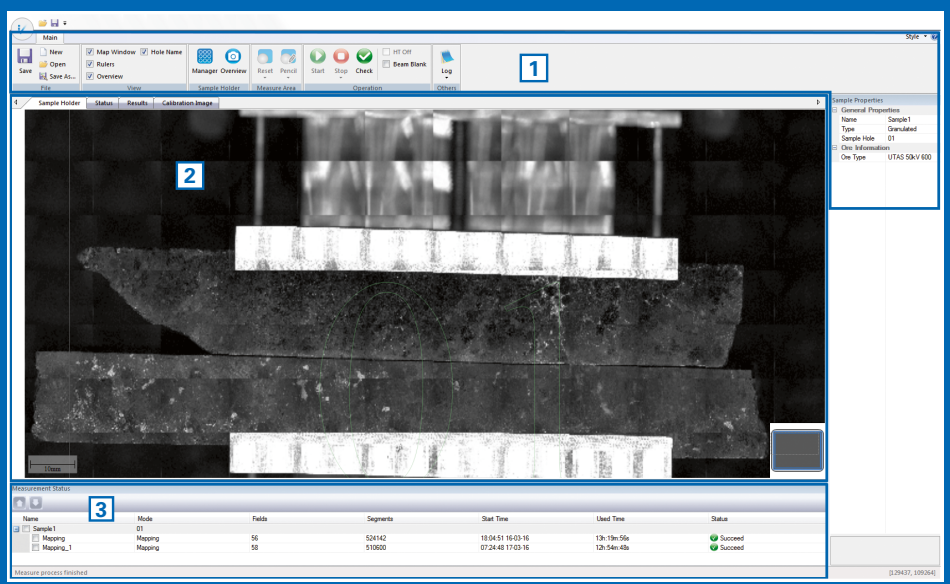
Once a measurement is completed, the results are automatically saved and the data can easily be reviewed, reprocessed, viewed and exported as charts and tables.

AMICS Software example performed on drill cores

1 Measurement control
- create, open or save measurement templates
- manage sample holders
- create overview images
- check, start and stop measurements

2 Sample view
- see sample and position
- set measurement area
- check progress

3 Sample data management
- manage samples and measurement types
- check measurement status



The AMICS Software

History and pedigree of AMICS

The Advanced Mineral Identification and Characterization System (AMICS) is the latest software package for automated identification and quantification of minerals and synthetic phases. It was developed by the highly qualified and experienced development team lead by Dr. Ying Gu, who invented the Mineral Liberation Analyzer (MLA) in the 1990's.

The key of the AMICS software package lies in its innovative analysis capabilities. The use of modern computing and software methodologies combined with a type of mineral fingerprinting enables extremely fast mineral identification and classification.

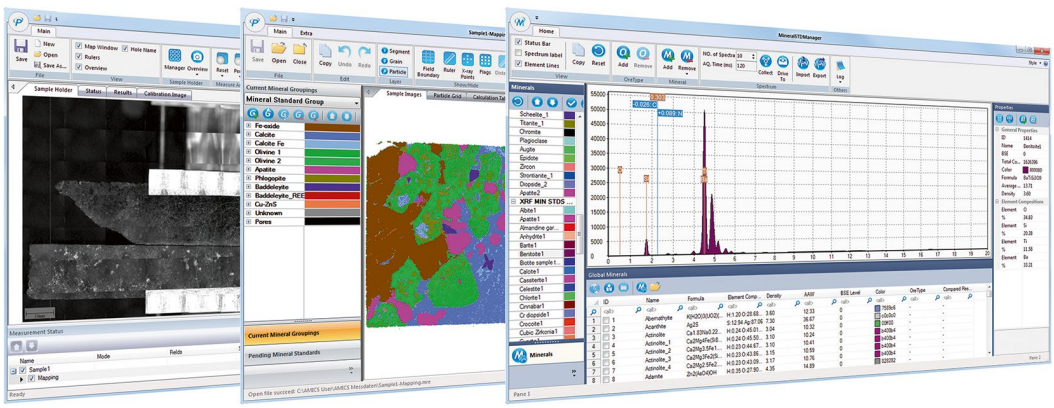
The data processing and handling of the software allows large data sets to be created, processed and moved with ease.

AMICS for the M4 TORNADO is a forward-thinking quantitative analysis system. Its versatility makes it ideal for use in both earth and material science research and industry applications.

The AMICS software suite comes complete with

- Investigator, an instrument control and data acquisition package
- AMICSProcess, a data processing and analysis package and
- MineralSTDManager, a mineral database management package.

AMICS Software Suite



Investigator AMICSProcess MineralSTDManager

Easy measurement automation

The setup of measurement areas is done interactively with the mouse. Multiple measurements or measurement types across the sample or stage can be added. Spatial resolution, dwell time, and mineral database for on-the-fly classification can be set during the configuration of the measurment. As the measurement areas and configurations are saved before each run, it is possible to reuse the same settings for each measurement, making it even quicker to get the measurement running.

Once completed, each measurement will automatically save the results in the file path defined during saving of the setup.

At the completion of the measurement, the AMICSProcess interface can be used to start working on analyzing the data, either on the instrument or with an offline workstation. When performing analysis and post processing on the instrument, mineral phases of interest can be revisited for more detailed analysis and classification.

Powerful result exploration, browsing and presentation

The measured data can be opened in AMICSProcess as soon as the measurement is completed, even if subsequent measurements are still running.

The sample or measurement can be visually represented in either a pseudo Backscattered Electron (BSE) image based on X-ray intensity, as an identified minerals view, or a mirror view. The mirror view allows a correlation of the image and mineral views. Image areas can be explored and zoomed in with the mouse. Images can be copied from here for reports.

To focus on a particular mineral, a filter can be used graying out other minerals. For more detailed analysis, the X-ray points can be activated. Each point can be separately analyzed and checked with regard to its classification. The spectra of unknown phases can be added to the mineral database as a standard for reclassification work.

The spectra window can also show the spectra of the classified mineral standard and the difference to the identified phase.

The *Particle Grid* function allows particles or their grains to be tabulated. The ordering can be configured to be grouped by modal mineralogy, calculated assay or elemental distribution, and sorted by area within each group. As with sample images, the minerals shown can be filtered. The X-ray points can also be activated to analyze and check classifications of points. This helps focusing on particular particles or mineral phases for reclassification work or analysis.

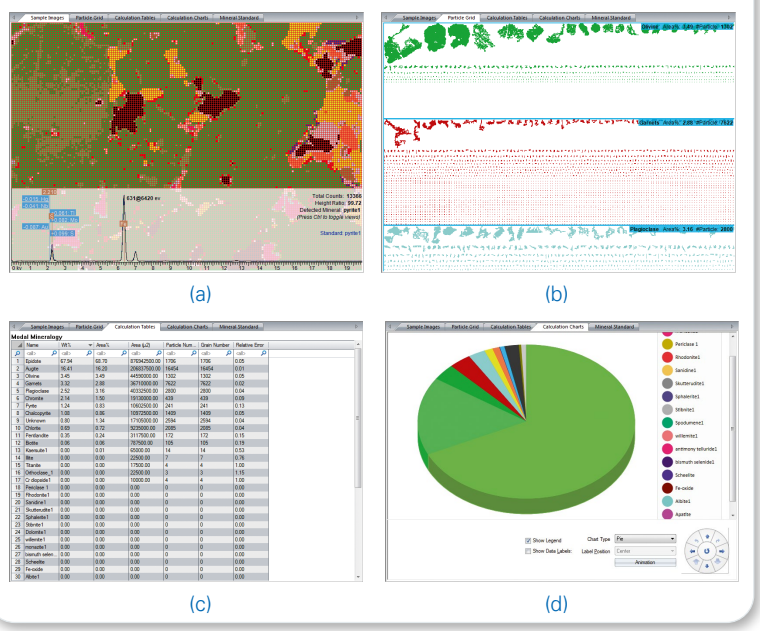
The modal mineralogy, the calculated assay and the mineral distribution can be shown in tables for quantitative results or visually represented as charts or graphs.

Flexible classification capability through database development

As many minerals are not fixed and composition can vary widely, the classifications need adjustment to take the local mineralogy into account. Here the standard database and re-classification helps ascertain the correct result.

Using the comprehensive database included will help identify and classify many minerals. For the rest, the mineralogy knowledge of the user combined with the mineral database manager allows the exact mineralogy to be determined and applied to the measured sample and any subsequent measurement.

Data exploration in AMICSProcess



(a) (b) (c) (d)

Data exploration: sample image (a), particle grid (b), calculation tables (c), calculation charts (d).

M4 TORNADO Instrument Highlights

Efficient sample excitation

Using a polycapillary X-ray optic, the X-rays from the tube are collected and focused onto smallest sample areas. Thus, a spot on the sample with a diameter < 20 µm (for Mo Kα) yields the same intensity as a 3 mm spot without the lens.

Fast spectrum acquisition

The M4 AMICS spectrometer is equipped with two XFlash® silicon drift detectors (SDD) enabling count rates of > 600 kcps (using dual detectors) combined with an energy resolution < 145 eV. The dual 30 mm² detectors allow a large solid angle for X-ray collection and parallel processing. For low X-ray yield samples (such as silicates), a dual 60 mm² detector setup is optionally available.

TurboSpeed stage

The large sample stage travels at a maximum speed of up to 100 mm/s. Combined with "on the fly" measurement, this ensures fastest possible mapping, as the detector is continuously collecting radiation.

Information on the element distribution can already be obtained with an acquisition time < 1 ms per pixel allowing a first overview of the sample composition within minutes. Additional image frames can be added for more detailed analysis. Due to the high precision of the TurboSpeed stage, such multi-frame measurements can be carried out routinely. Longer acquisition times provide even more analytical details.

Convenience and ease of use

Convenience and easy handling are provided for the user through:

- the EasyLoad function for fast sample exchange
- the large sample chamber, enabling a stage travel of 200 x 160 x 120 mm
- sample positioning supported by a fish eye camera and two optical video microscopes that show approx. 1 mm² and 100 mm²
- auto focus function for setting the sample height correctly
- mosaic (tiled) images of high quality (stitching, shadow correction) for large area maps
- distribution analysis with HyperMap, which collects complete data sets, supporting offline data evaluation.

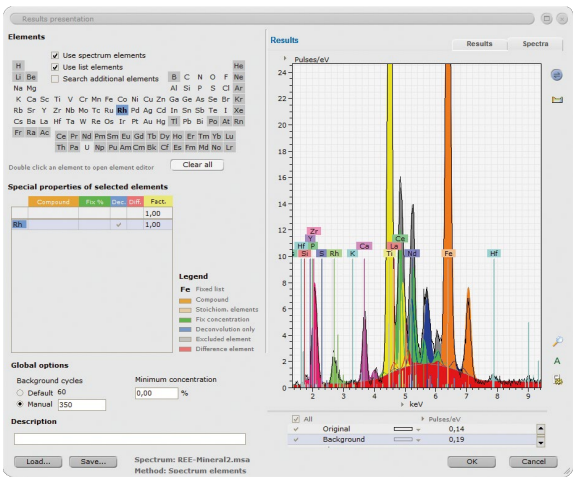
M4 TORNADO software

The M4 TORNADO software controls safety circuits and allows the instrument configuration for image and spectra acquisition during measurement. It also controls mosaic image generation, point and multi-point analysis and hyperspectral mapping. Qualitative and quantitative analysis and data mining provide detailed insights into the examined sample.

Accurate and flexible quantification

To help identify minerals, the quantification of unknown phases is necessary in many cases. To make this process simple, the M4 TORNADO software uses standardless analysis based on fundamental parameter (FP) models. The software module M-Quant provides reliable results on the composition of bulk samples.

M4 TORNADO Software Quantification



Technical Specifications

Sample types	Solids, particles, liquids
Sample chamber size	WxDxH: 600 mm x 350 mm x 260 mm
Stage	WxD: 330 mm x 170 mm, Max. weight load: 5 kg
Measurement media	Air or oil free vacuum, ready for measurement within 100 s
Sample travel Max. travel Mapping travel Travel speed	 WxDxH: 200 mm x 160 mm x 120 mm WxD: 190 mm x 160 mm Up to 100 mm/s with TurboSpeed stage
Sample view	2 simultaneous live images from above with 10x and 100x magnification for sample overview and precise positioning Lateral fisheye camera for the sample chamber overview
Excitation	High brilliance X-ray tube with polycapillary X-ray optic
Excitation parameters Target material Tube parameters Spot size Filters	 Rh 50 kV, 30 W Less than 20 µm for Mo Kα with polycapillary lens Up to 5 filters
Detection	Dual XFlash® silicon drift detectors with simultaneous use
Detector parameters Sensitive area Energy resolution	 Dual 30 mm² or optional dual 60 mm² < 145 eV at 300,000 cps per detector
Instrument control	State-of-the-art PC, Windows 7
Instrument control functions	Complete control of tube parameters, filters, optical microscopes, sample illumination and sample positioning
Spectra evaluation	Peak identification, artifact and background correction, peak area calculation, quantification with standard-based and standardless models; AMICS Mineral Identification and Characterization by Mineral Standard Database
Distribution analysis	"On the fly" measurement, HyperMap capability, measurement by point grid
Result presentation	Quantification results, statistical evaluation, element distribution (line scan, mapping), AMICS mineral map, multiple mineral groupings, particle grid, calculation tables and charts
Power requirements	100–240 V (1P), 50/60 Hz, ~500 W, max. 1080 W
Dimensions	WxDxH: 815 mm x 680 mm x 580 mm, 130 kg*
Quality & safety	DIN EN ISO 9001:2008, CE certified Fully radiation protected system; radiation < 1 µSv/h

*Depending on configuration

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