IMPROVEMENT OF ACCURACY AND PRECISION IN NON-DESTRUCTIVE ASSAY OF WASTE FROM DECOMMISSIONING OF NUCLEAR INSTALLATIONS

T. Buecherl, A. Elhardt
Institut fuer Radiochemie, Technische Universitaet Muenchen

G. Caspary
Institut fuer Sicherheitsforschung und Reaktortechnik, Forschungszentrum Juelich

ABSTRACT

An analysis and evaluation system for the characterization of radioactive waste from nuclear installations for both declaration and free-release measurement is presented. Based on the consideration of measurement data, a-priori information and databases at the same time, accuracy and precision in activity determination are improved and the results are set on a more reliable basis.

INTRODUCTION

Huge amounts of different waste streams arise during the decommissioning of nuclear installations. The characterization of these waste streams is frequently supported by non-destructive assay techniques. Depending on the objective different techniques are applied like integral gamma-counting for free-release measurements or gamma-scanning for activity determination.

In praxis all techniques have in common that the measurement result strongly depends on the activity and matrix distribution throughout the measuring object which are only specified/known in rare cases and are approximated by rather simple models. A statement concerning accuracy and corresponding uncertainties is therefore usually based only on counting statistics. In some applications the uncertainties are "corrected" by empirical factors which should take into account the lack-of-knowledge on the real matrix and/or activity distribution.

To overcome this unsatisfactory situation, a software package was developed for the determination of activities and their uncertainties on a more reliable basis using all available information and considering different density and activity distributions being consistent with the measured data. Additionally, the software package is applicable for reducing the efforts for calibration, evaluation and QA/QC for both declaration and free-release measurements.

INFORMATION

General

Information on an object to be characterized may be available from different sources. While in conventional data evaluation measuring data for the individual techniques are evaluated to a large extend independently, the software package aims to integrate this information, i.e. all measuring information on an object is used at one time for evaluation. Additional consideration of a-priori information and databases further reduce the lack-of-knowledge, thus improving accuracy and precision.

These different categories that are considered by the software package are briefly discussed next.

Measuring Data

Information on the activity content of an object can be gathered by dose rate measurement, integral gamma-counting or segmented gamma-scanning. The latter can be applied in different modes (e.g. multiple rotational scan, swivel scan etc.) resulting in a more or less detailed information on the activity distribution. This (integral) count rate (distributions) measured on the outer side of an object must be corrected for shielding effects. For this purpose information on the container, shielding structures and on the matrix composition and distribution are required. This can be based on the results of simple weighing, on measuring the outer dimensions of the object and/or on radiographic and tomographic techniques.

A-priori Information

This type of information can be separated in general, matrix related and activity related data. The first contains information on the producer, his license (i.e. the maximum amount of activity (for each individual nuclide) he is allowed to handle with in his installation) and the date of production of the radwaste. Information on the container (e.g. type, dimension, material, mass etc.) can be assigned to the matrix related data as well as information on inner containers or shielding structures. Knowledge on the type of conditioning (e.g. raw, cemented, bituminized or super compacted waste) may limit the possible density range of the matrix. Based on a categorization which correlates nuclides with a certain waste type the number of nuclides to be considered in evaluation can be cut down, thus acting as activity related information. The same holds if either nuclide vector, nuclide inventory or declaration is known.

Databases

Information on general properties of nuclides like gamma-lines half life, transition values, decay schemes and cross sections as well as on material properties like density and composition are available from databases. More specialized databases contain the nuclide specific limits for free-release measurement, the parameters of containers and of the detector configurations used in the measurements.

THE SOFTWARE PACKAGE

General

The basic idea the software package is working on is to consider all available information to set the data evaluation and analysis of an object on a more reliable basis. Since this information is that manifold and diverse a special module for data acquisition converts the data into a common internal data format. Based on this data an iterative evaluation and analysis routine is applied, resulting in the most probable nuclide specific activities and their uncertainty ranges and the corresponding matrix compositions.

As can be seen from Fig. 1, the software package is set up by individual modules. This modular structure enables easy adaptation of future extensions, e.g. when considering additional data or new consistency checks. In the following the individual modules are briefly introduced.

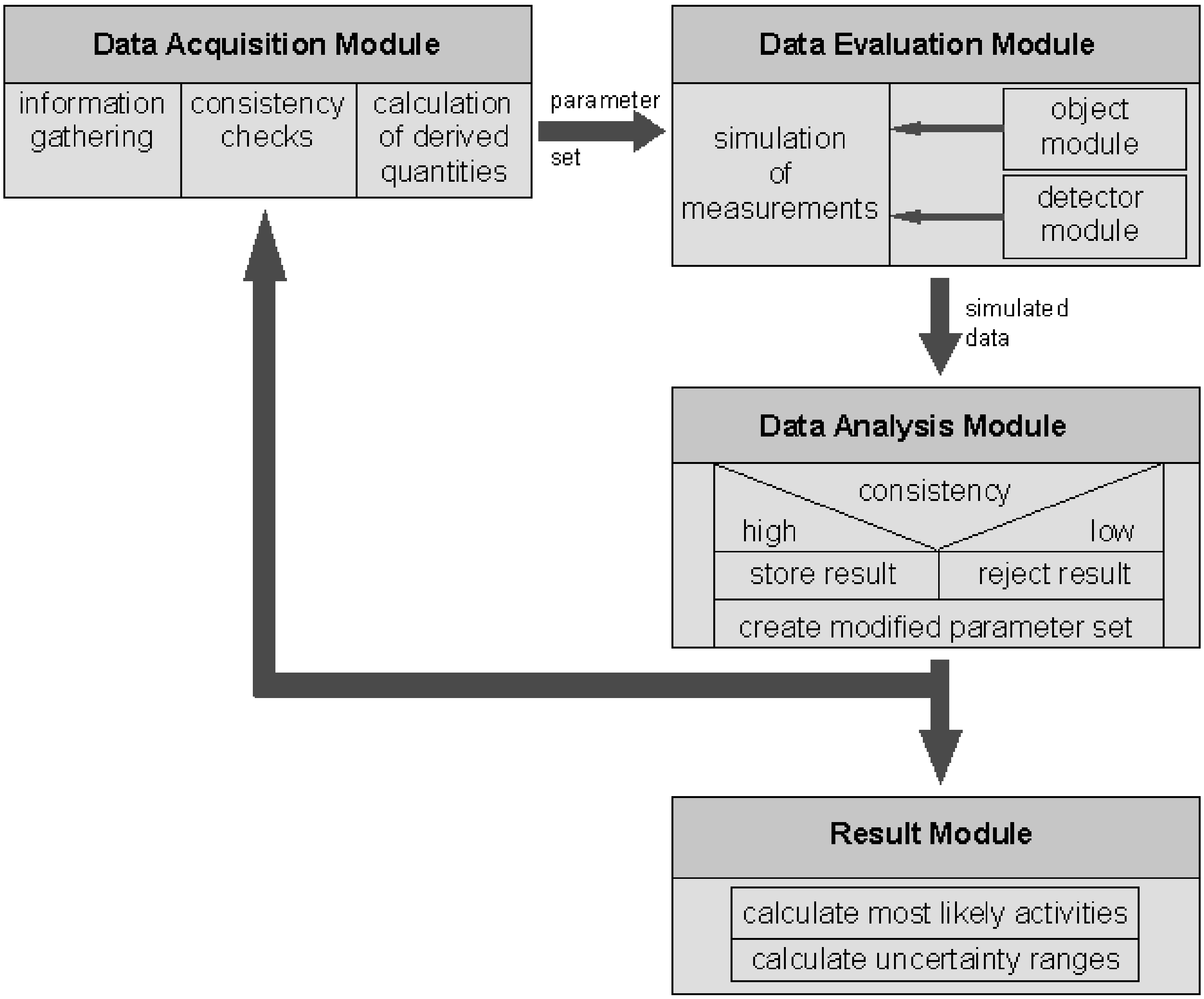

Fig. 1 Schematic representation of the main part of the modular software package

Data Acquisition Module

The data acquisition module consists of three parts. The first is responsible for gathering all information from the three different categories, the second for consistency checks and the third for calculating derived quantities.

The software package is using a well defined internal data format in which all external information must be converted. Usually, the resulting data from two different measuring systems, even when produced by the same company, are hardly given in the same format, thus requiring individual import converters. For the systems used by the authors (e.g. described in [1, 2, 3]) converters are already available. Other systems can be adapted on request. After finishing the data import consistency checks take place verifying that the data are correct and consistent (simple example: if the measured mass and the net mass of the container are known, the first must be larger than the latter). Then derived quantities are calculated. Those can be simple values like the mean density, which is calculated from a given net volume of the container and the net mass derived from the measured mass and the net container mass, or complex information like the activity distribution of one nuclide within the object, which is derived from the measured count rate distribution of segmented gamma-scanning (Fig. 2) or the matrix information derived from radiography (e.g. Fig. 3). Once again consistency checks verify that the derived data is acceptable, e.g. the activity distribution is only located within the container. Manual corrections are still possible (Fig. 3).

All these data (parameters) then act as input for the following data evaluation module.

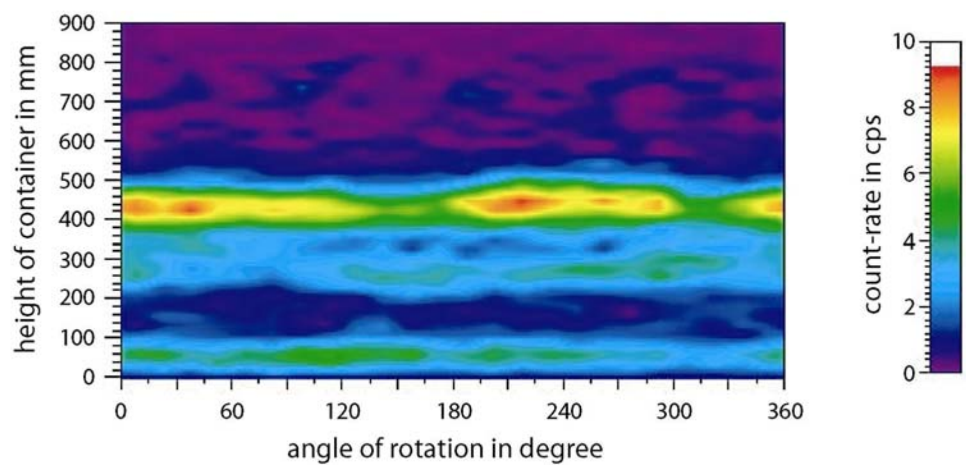

Fig. 2 Measured count-rate distribution for Cs-137 resulting from a multiple rotational scan in segmented gamma-scanning [1] as an example of possible input data for the software package.

Data Evaluation Module

In this module all or a pre-selectable number of measurements are simulated based on the input information from the data acquisition module. Preferably those measurements are simulated whose measuring data are available. This requires two sub-modules which are attached to this module. The first determines the response functions of the detector systems used in the measurements (called detector module), the second provides a detailed description of the object under investigation (object module). This object description can either be set up automatically by the data acquisition module or manually for test and calibration purposes.

The simulation data then are analyzed in the analysis module.

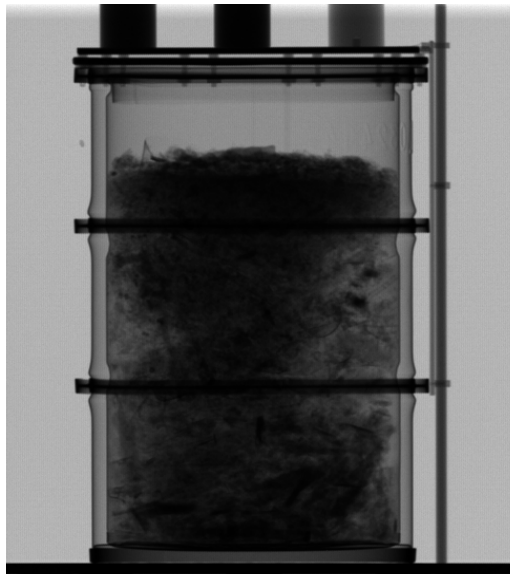

Fig. 3 Digital radiography of a 200-L waste package containing an inner container filled with raw waste. It was measured by the Integral Tomography System [1] using a Co-60 transmission source. The rods on the right side and the cylinders on the top of the drum are used as internal calibration standards.

Data Analysis Module

The results of the simulations are compared with the measured data and the corresponding a-priori data. Depending on the level of consistency two different procedures can take place. First, if the consistency is high, the input data are stored in a database as one possible solution. Or, second, if the consistency is below a pre-defined limit, the parameters are rejected. In both cases, the parameters are then modified within their uncertainty ranges and/or limits and re-admitted in the simulation process, i.e. these new parameters are fed in the data acquisition module for consistency checking. If this fails this parameter set is rejected and a new one is determined and re-admitted, otherwise new derived quantities based on these modified parameters are determined and a new data evaluation takes place. If all possible modifications are completed or a break criterion is fulfilled, the achieved results are summarized in the result module.

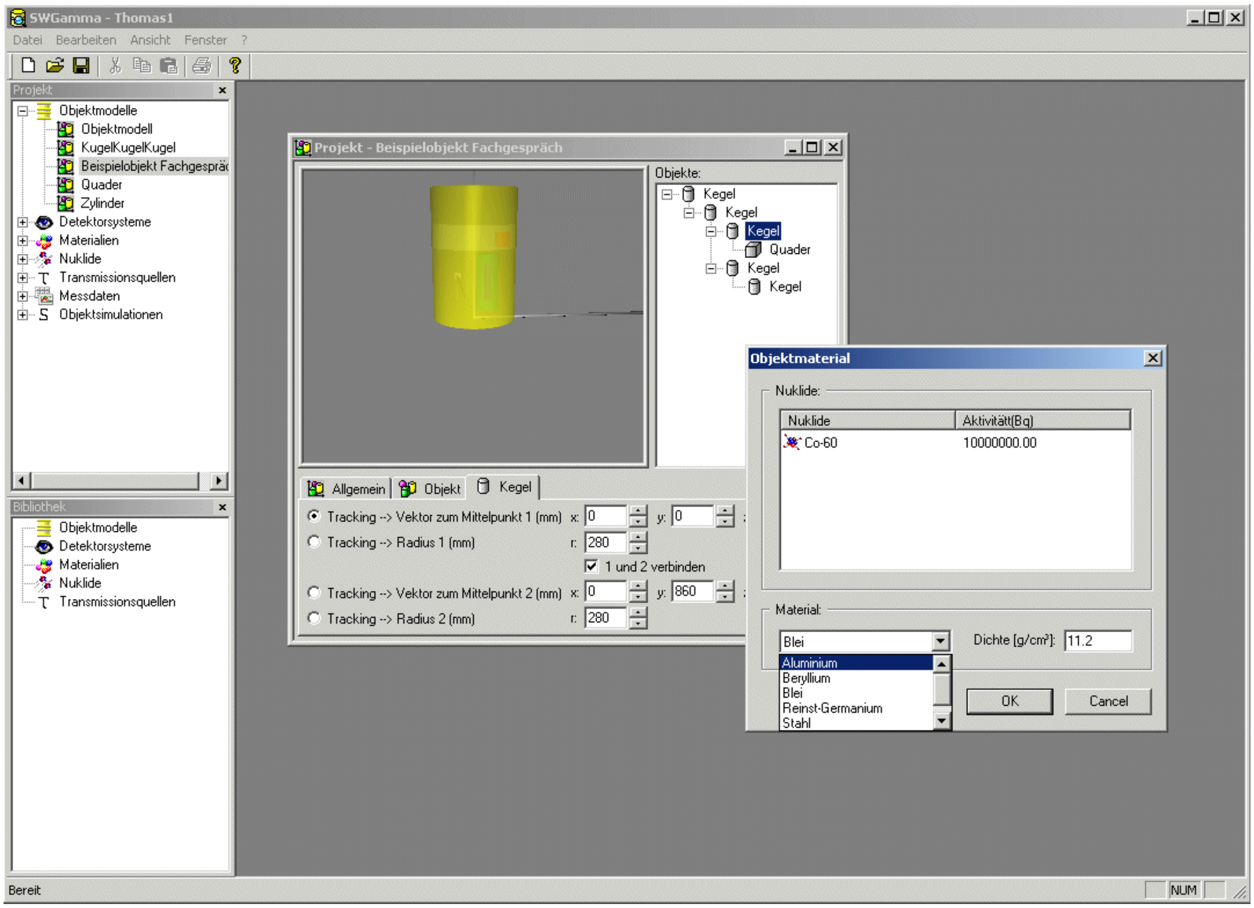

Fig. 4 Screenshot of the interface of the software package when manually selecting/changing the material composition of a created object.

Result Module

Based on the results of the simulations stored in the database, the most likely nuclide specific activities and their uncertainty ranges are calculated. These results and all data used are stored in one file, thus enabling the retracing of the evaluation for QA/QC purposes.

CONCLUSION

With this software package a gap in the available data evaluation procedures in non-destructive characterization of radioactive waste will be closed. It will consider all available information as there are measurement data, a-priori information and knowledge from databases in activity and uncertainty determination. First validation tests actually performed have shown its potential and will be used to verify its improvement compared to conventional evaluation procedures. An English version of this software package will be available in the near future on request.

As a side effect of the development of the software package the detector and object modules can be used for calibration of measuring systems and for design studies of new measuring systems.

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