

# Dose assessment and dose optimisation in decommissioning using the VISIPLAN 3D ALARA planning tool

F.Vermeersch  
SCK•CEN,  
Boeretang 200, 2400 Mol Belgium

## Abstract

The optimisation of radiological protection of the workers in nuclear industry is an important part of the safety culture especially in the field of decommissioning where we are confronted with a radioactive environment that is in the process of constant change. The application of the ALARA concept (to keep exposures As Low As Reasonably Achievable) is not always straightforward in such cases. A good ALARA pre-job study must be performed and should contain predicted doses in the work area and investigate the effects of geometry, material, source or work position changes. This information provides a quantitative basis to select between various alternative work scenario's for a specific operation.

In order to handle this information SCK•CEN developed the VISIPLAN 3D ALARA planning tool. This PC-based tool makes it possible to create and edit work scenario's taking into account worker positions and subsequent geometry and source distribution changes in a 3D environment.

The presentation will show the current status of the tool and its application to the decommissioning of the BR3 reactor and other installations. New developments will also be presented regarding the geometric and radioactive characterisation of a decommissioning site. The use of human motion simulation tools in ALARA assessment will also be discussed.

This will show how new developments of software and measurement tools can help dealing with the new challenges of decommissioning in the field of dose optimization.

## Introduction

In order to perform a good ALARA-study for a planned work, information has to be gathered concerning the site geometry, the distribution of the sources, the work planning, the shielding options, the costs,... All these aspects have to be considered to arrive at an adequate ALARA-decision. The information has to be organised, structured and analysed to determine the best approach for the planned work. Tools for supporting the ALARA-analyst are clearly desirable in this context.

A large portion of ALARA is the "As Low as" part concerning the reduction of the dose. This means that the ALARA-analyst must be able to assess the dose in the working area and investigate different shielding options. The need for a fast 3D-calculational tool is clear due to the geometrical complexity of many work environments in nuclear industry.

The VISIPLAN 3D-ALARA planning tool develop at SCK•CEN provides an answer in a variety of environments down to the level of the dose uptake by the individual worker.

The tool and its capabilities are presented in the next section. Examples of applications in decommissioning activities are given thereafter. New developments are described at the end of the paper.

## The VISIPLAN 3D ALARA planning tool

The tool is developed to assist the ALARA analyst in the ALARA pre-job studies, in the dose calculations but also in the communication between the stakeholders during the ALARA evaluations. The method used for the dose assessment is based on a point-kernel calculation with an infinite media build-up correction. The method has proven its applicability in dose assessment in the radiation protection and dose optimization field<sup>1,2,3</sup>.

The tool calculates the dose account for different work scenario's defined by the ALARA analyst, taking into account worker position, work duration and subsequent geometry and source distribution changes.

The VISIPLAN methodology is based on four major steps, model building, general analysis, detailed analysis and follow-up.

In the first step the computer model of the environment is build based on the known geometry, the materials information and information about the radioactive sources of the site. This results in the basic geometry from which other geometry's, mostly with supplementary shielding, can be derived. When the sources are known a calculation of the field can be performed immediately.

In the general analysis phase the calculated dose rate field is studied and suggestions about shielding techniques are tested and analyzed using calculated dose maps for each of the suggested shielding geometry's. Once a shielding geometry is chosen a detailed dose calculation can be performed along a trajectory consisting of a series of tasks, characterized by a position, a task description and a work duration. The trajectories can be calculated in different shielding geometry's.

Scenario's can then be build through a selection of trajectories calculated in the different geometry's. The comparison of the scenarios leads to an optimization, with respect to the dose uptake of the work to be performed.

In the follow-up stage the dose accounts of the workers are compared with the predictions from the model. When large deviations occur a reassessment of the work can be performed by adapting the model to the new information. This makes it possible to adjust, and thus to further optimize the work during its progress.

The VISIPLAN tool has been applied successfully for ALARA work planning in different environments going from nuclear reactors to decommissioning sites and has stimulated a more rigorous implementation of the ALARA concept.

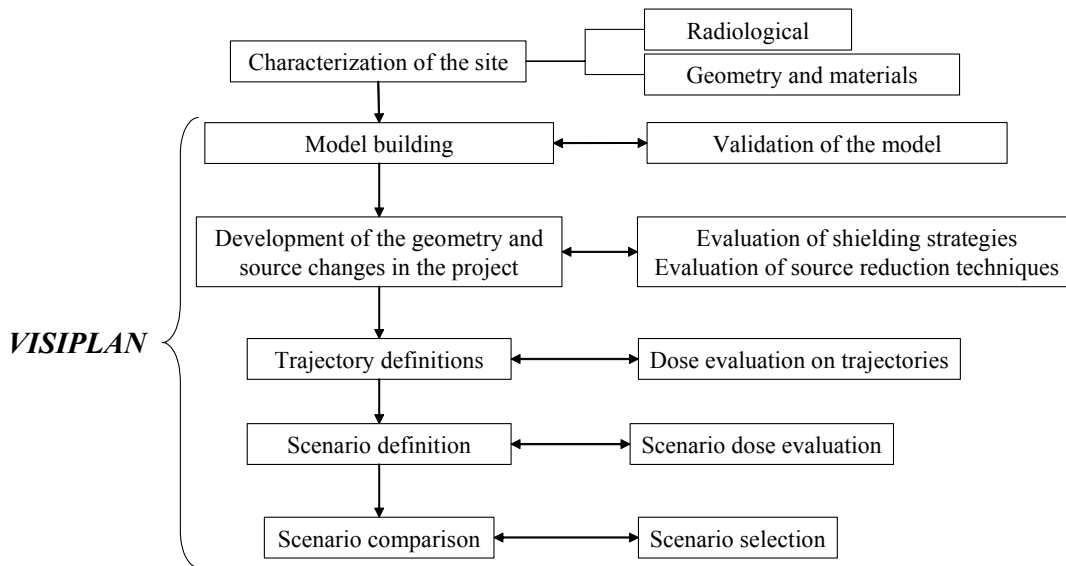


Fig. 1. The different steps where the VISIPLAN 3D planning tool is used in the ALARA analysis

## Applications

### ▪ The BR3 decommissioning project

The BR3 reactor was the first PWR plant to be built in Western Europe. Started in 1962, it has been definitely shut down in 1987. It is a low rated plant with a net power output of 10.5 MWe.

Nevertheless it presents all the features of commercial light water reactors, has undergone the same type of life, water chemistry, irradiation etc.

At the end of 1989, the European Commission selected the BR3 as European pilot decommissioning project within the framework of its five year Research and Technological Development programme. The Commission selected four pilot projects, covering almost all kind of nuclear reactor types and facilities (PWR, BWR, AGR and reprocessing plant).

The VISIPLAN tool was used on several occasions during the BR3 decommissioning process in order to evaluate the dose uptake and optimize the work with regard to the dose<sup>4,5</sup>.

A simplified 3D-model of the site under the operating deck was developed which includes the main structures of the site (Fig. 2). The geometrical and materials data was taken from technical drawings.

The source strengths were determined based on a set of contact and ambient dose rate measurements well distributed over the whole site. The source strength were then determined using a source inference technique. Spectral analysis revealed that Co-60 was the major isotope contributing to the dose. As a consequence we modeled sources as pure Co-60. A good agreement was found between the measured and calculated doses.

A dose assessment was performed based on the work description list provided by the work planner. This work description list contains information on the work to be performed the number of workers involved and the time spent at certain positions on the work floor.

Based on this information the tools in VISIPLAN provided information on the collective dose and the individual dose for the work as described in the list. The different tools in VISIPLAN also allow assessing the influence of the task order, or the introduction of shielding during the tasks. The results obtained together with other input (financial, feasibility,...) guided the decision makers to find an optimum solution for the work plan.

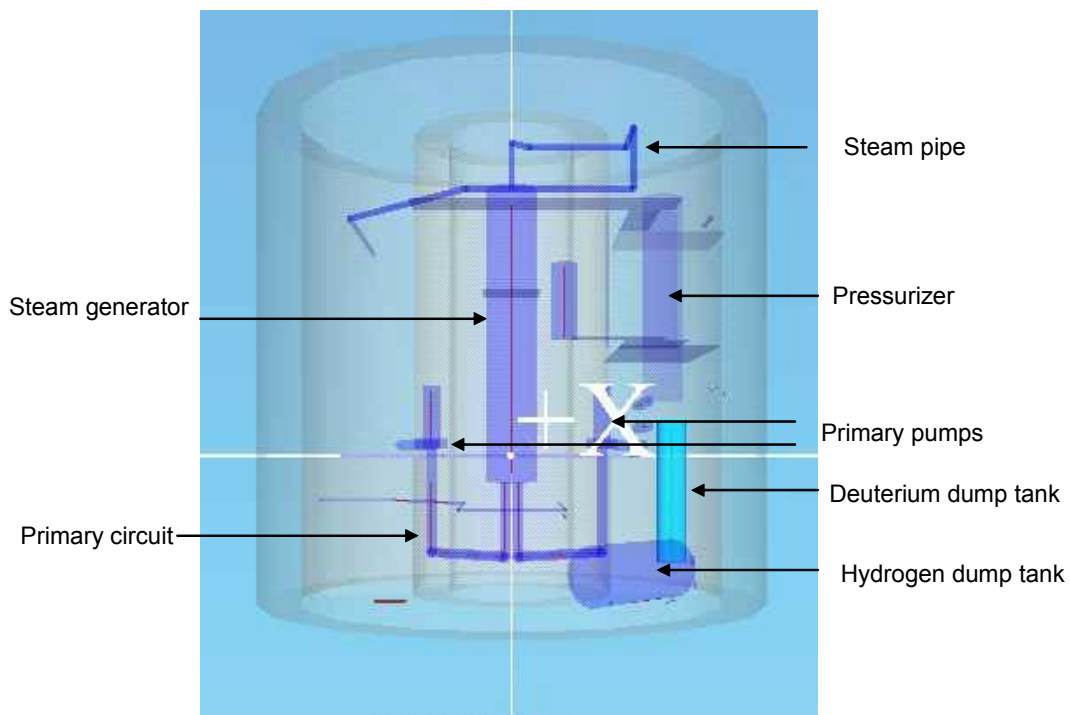


Fig. 2. VISIPLAN model of the BR3 area under the operating deck

- **Hot cell 41 refurbishment**

Cell nr 41 was already out of service since several years, when the decision was taken in 1999 to dismantle its contents to equip it in the framework of a new program, about the reinstrumentation of irradiated fuels. From a historical point of view, this cell was used successively since the years 60 for the reprocessing of ceramic fuels, the manipulation of Pu-fuel and finally for the reprocessing of highly uranium enriched irradiated fuel using chemical extraction techniques.

Before putting the dismantling of cell 41 into practice, a detailed ALARA study was carried out. The first step consisted of a radiological measurement campaign inside the cell. TLD-dosimeters (thermoluminescent) were used to obtain dose rate values. Smear samples were also taken at several representative points of the cell. These samples were afterward measured to obtain an estimation of the transferable contamination. Several smear samples were also measured in gamma spectrometry to obtain an estimation of the isotopic composition of the contaminants.

Based on the measurement results mentioned above an extensive ALARA study was carry out using the software VISIPLAN.

In the framework of the dismantling of cell 41, different shielding options of the hot-spots were studied.

Based on the different trajectories that were calculated, a scenario can then be build allowing having a global view of the different operations to be carry out and of the dose levels that will be received by the different workers. A global collective dose of 21 man.mSv was foreseen (taking into account the uncertainties defined in the system, between 15 and 28 man.mSv). The collective dose measured was 26 man.mSv, a good agreement taking into account the uncertainty in the assessment<sup>6</sup>.

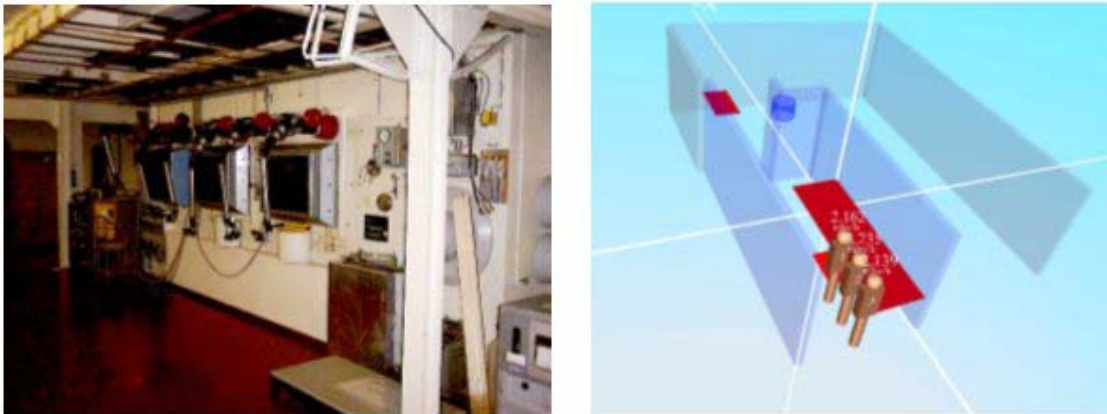


Fig. 3. The cell 41 refurbishment (Outside view of the hot cell (left), simulation in VISIPLAN (right))

- **New developments**

The VISIPLAN program is under constant development to enlarge its capabilities and to answers to requests from our users. The developments occur in different area's going from improvements in the geometric library and calculation speed to the establishment of links with other software and measurement tools.

In order to be able to cover more geometric environments with the VISIPLAN software new volumes are introduced and tested such as the cone, conic tube, and cut spheres enabling a more realistic representation of a radioactive environment. The need to analyze bigger and more complex environments spurred the development and implementation of a sorting algorithm to select only the volumes having an influence on the dose assessment. The implementation of this algorithm leads to a faster dose assessment in a complex environment.

The need to analyze more complex environments directed us also to establish a link with a CAD tool.

An interface was established between VISIPLAN and the Microstation CAD package through a collaboration between Tractebel Engineering and SCK•CEN. This interface enables the transfer of the geometric data of the CAD system to the VISIPLAN system reducing the time spent in the geometric building process of the environment. The interface is operational and is now being extended to the new volume type described above.

SCK•CEN collaborated with the VISIPLAN 3D ALARA planning tool and the experience gained with it in the European 5th framework program called VRIMOR standing for "Virtual Reality for Inspection, Maintenance, Operation and Repair". The aim of the project was to show the viability of an integrated approach to minimize occupational exposure through the combination of different technologies including gamma scanning, geometrical scanning, human motion simulation tools and a radio-geometrical modeling tool<sup>7</sup>. Now we have reached a stage in which we have established a set of interfaces enabling the data transfer to and from the different tools involved in the project. This technology has been applied at the Almaraz Nuclear Power Plant in Spain and resulted in a Technological and User Perspective Review Report by Tecnatom Spain<sup>8</sup>.

The interfaces developed involve the human motion data obtained by the human modeling tools ErgoDose developed by NNC Ltd UK and HesPi by Universidad Politecnica de Madrid, Spain. The radiological characterization makes use of the gamma scanning interface to import and analyse gamma scans measured with the EDR gamma scanner from CIEMAT<sup>9</sup>. A third interface was established between the Light Form Modeller tool from Z+F Ltd UK enabling the transfer of a scanned geometrical environment to VISIPLAN.

The availability of these data exchange interfaces between the different tools of the partners allows an integrated approach to ALARA in maintenance outage and repair in existing Nuclear Power Plants going from characterizing the work area to the work simulation, dose assessment and dose optimization.

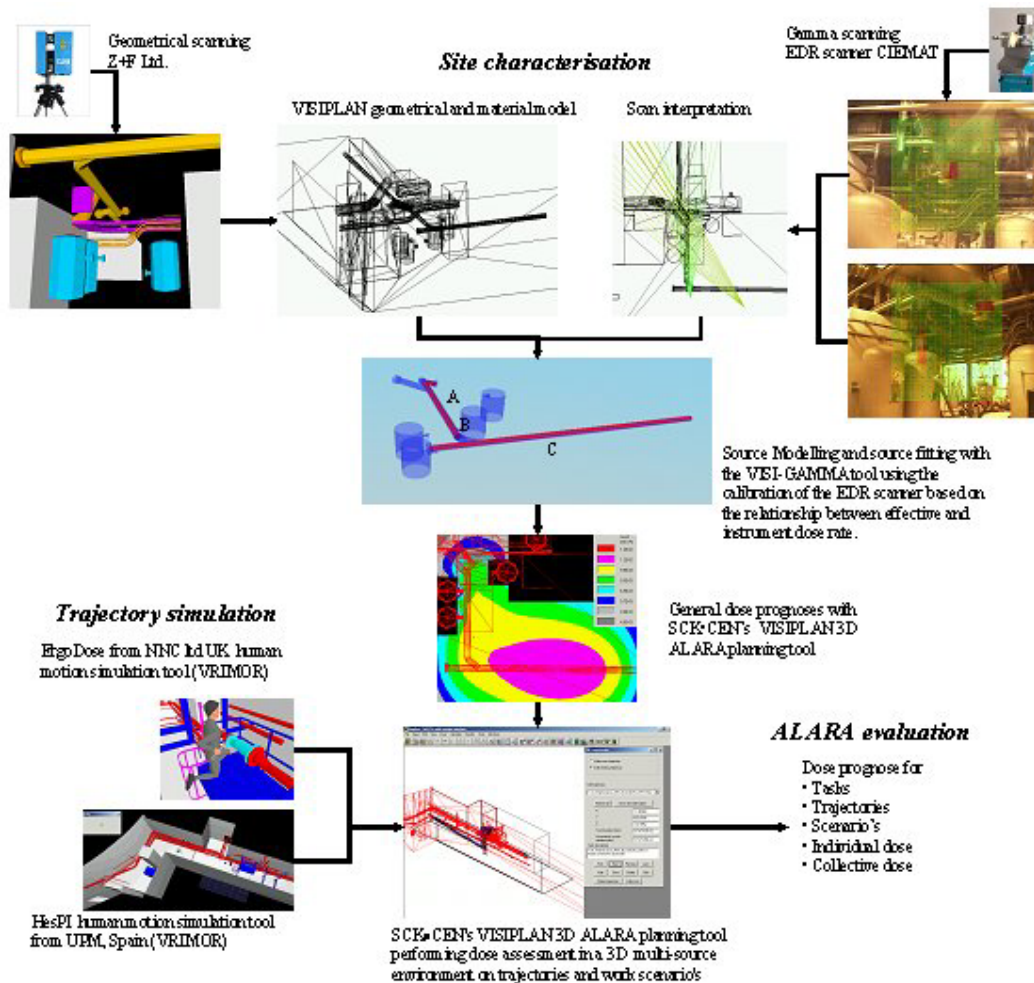


Fig. 4. Integrated approach to the ALARA evaluation developed in the VRIMOR project

## Conclusion

The VISIPLAN tool set provides the ALARA analyst with a state of the art dose assessment and dose optimization tool.

The tool assists in:

- Geometric and source modeling
- Source strength evaluation
- Dose assessment in a 3D environment
- Trajectory Simulation and dose evaluation
- The flexibility to edit the radioactive environment or trajectories in order to optimize the planned task
- Communication between the ALARA stakeholders.

The tool has proven to be valuable for dose optimization applications going from design of new installation through maintenance up to decommissioning.

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