Development of the VISIPLAN ALARA planning tool

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Abstract

The application of ALARA and the dose assessment for work in a complex nuclear installation is a difficult task. Dose values are influenced by the geometry of the installation, the source distribution, the shielding configuration and the work organisation. The dose assessment becomes even more difficult in changing environments such as decommissioning sites. In order to assist the responsible for ALARA work planning we developed the VISIPLAN ALARA planning tool which makes it possible to plan the work in a 3D-environment based on geometrical, material and radiological information together with information regarding work organisation.

1. Introduction

ALARA calculations for work planning in complex nuclear installations are difficult. The aspects of geometry, source distribution and shield geometry play an important in the dose assessment. The organisation of the work, type of work, work duration are non-negligible in the ALARA considerations. Several work scenarios need to be considered and compared before deciding on the final approach to the problem. These scenario's can differ in the type, location, duration of the work, the plant geometry, the shielding geometry and even the source distribution. This is especially the case in decommissioning activities where the geometry and the source distribution of the working area change over a relatively short period of time. In order to structure and streamline this information we developed the VISIPLAN ALARA planning tool. This PC-based tool makes it possible to create and edit work scenario's taking into account worker position and subsequent geometry and source distribution changes.

The general methodology at the base of this tool will be described in section II. Examples of some application of the first version of the program in real situation will be given in section III. The dose calculations within the program are based on the point-kernel technique with the infinite media buildup method. This method has been proven to be fast and sufficient for most applications in the field of dose assessment.

2. The VISIPLAN Methodology

Different stages can be recognised in the ALARA-analysis of an intervention or a routine work in a radiative environment. They are:

- The Information gathering and model building stage
- The General analysis stage
- The detailed planning stage
- The follow-up stage

Each of these stages will be described in the following subsections in relation to the use of the VISIPLAN software.

2.1. Information gathering and model building stage

A first step in the VISIPLAN approach is the gathering of information about the working area in order to develop an adequate model for dose calculations. This information includes the geometry, the materials and the radioactive sources of the installation of interest.

2.1.1 Geometrical information

The geometrical information can be build from technical drawings or can be obtained through measurements on site. The latter can be realised by scanning techniques such as laser scanners, photogrammetric techniques or other survey instruments. The choice of the method will greatly depend upon the complexity of the situation and/or the required geometrical detail needed in the model. The geometrical information is translated into the model by using primitive volumes such as boxes, spheres, cylinders and tubes. This set of volumes is generally sufficient to describe most working areas found in nuclear installations.

2.1.2. Material information

Material information is gathered from technical drawings, technical reports and from experts on-site with a knowledge of the site history. The material information is entered in the model as standard materials such as concrete, water, iron... and are attributed to the different volumes. The density of these materials can be changed according to the needs of the model. It is also possible to define mixed materials in order to make an approximation for the absorption of complex structures (creation of a homogeneous mixed material).
The buildup and attenuation coefficients are taken from ref. [1].

2.1.3. Radiological information

Radiological information is gathered from dose measurements or from detailed information about the sources used on the site.

The information about source position, source strength and source composition if available can be entered directly into the program. The source composition is defined by selection of isotopes in an isotope list. Isotope mixtures and spectra can also be defined.

The program provides a tool to perform a source inference calculation to estimate the source strengths based on a dose mapping and on the knowledge of the source positions and the isotopic composition of the sources.

The acquired data is organised in a database, allowing for easy queries and data maintenance. The geometry and the material information can be displayed on screen in a 3D-wireframe model as shown in figure 1.

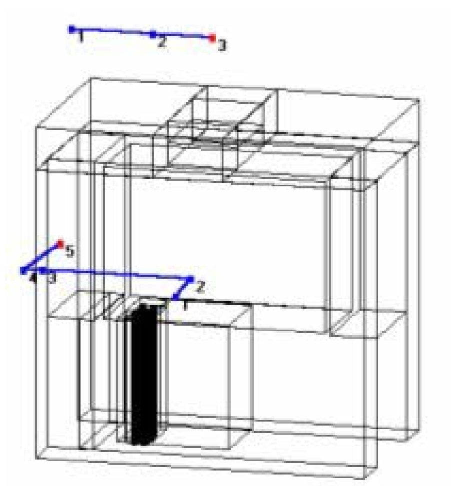

Figure 1. 3D-wireframe model of a hot cell with shielded containers below the floor.

2.2. General analysis stage

Once the model is defined we can start with the analysis of the working area. This first model is stored as Take 1. A "Take" is defined as a fixed environment defined by the geometry and the source distribution.

In this stage different maps of the radiation environment can be calculated for the different working areas. The dose rates can be displayed as contours or as colour patterns on pre-defined grids perpendicular to the x-, y- and z-axes. This allows a quick detection of the high dose rate areas. A graphical interface is provided to display the contribution of each source to the dose at each location in the grid. This tool helps the analyst to suggest possible shielding schemes.

Different shielding configurations can be introduced in the model and analysed on their effectiveness before going to the detailed work planning. Each shielding solution or change in the geometry is stored as a different "Take", which makes it easy to keep track of the different shielding solutions or geometry changes that are proposed.

The dose maps produced during the general analysis phase also have an added value for communicating the possible risk area's to the workers. The overlay of these maps on the plan view of the site gives the worker a clearer picture of the radiation risks, so enhancing the awareness of the worker.

2.3. The detailed planning stage

The detailed planning phase is aimed at producing a set of scenario's describing the work with an assessment of the dose to the workers. In the VISIPLAN methodology a scenario is build from a set of trajectories selected from the different "Takes".

A trajectory consists of a sequence of tasks to be performed in a fixed geometry and source distribution ("Take"). These trajectories contain information involving the description, the location and the duration of the sequential tasks to be performed. The dose account is then calculated for the trajectory based on the radiological and geometrical information of the installation. Information about the type of work, work description and work duration is gathered from the knowledge of experienced workers. Uncertainties on the work duration can be taken into account making it possible to calculate maximum and minimum values for the acquired doses.

The trajectory results can be examined on screen or printed in a trajectory report for further reference. The displayed information is in graphic and text format. The graphic information for a trajectory contains the accumulated dose versus time, the dose rate and the dose per task. More information per task can be displayed such as the contribution of each source to the accumulated dose for the specified task. Based on this information a further optimisation can be performed. This can be the optimisation of the shielding solution or the use of other techniques to reduce the source contribution to the dose, such as source strength reduction through chemical cleaning, or the reduction of the task duration through the use of more time efficient work methods.

New shielding options can be studied by performing an update of the geometry in a new "Take". The defined trajectories can then by re-run and examined.

From a set of trajectories we can now build a "Scenario" as a sequence of trajectories from possible different takes.

A worker or a group of workers is then assigned to a chosen trajectory. This method allows to calculate the collective dose for the work as well as the individual dose specified for each worker. The analysis of the different scenarios leads to the most suitable scenario for the work.

2.4. The follow up stage

The graphs and task lists produced in the detailed planning stage make it possible to perform a thorough follow up of the dose account during the work. This is achieved trough comparison of the predicted and the received dose. Large deviations between both are an indication that risks which where not foreseen in the planning stage are present on the work floor. An appropriate answer, and new prognoses can then be formulated based on new measurements and an adaptation of the model including the detected risks. This approach makes it possible to update the model during the work progression and to suggest scenario's with a low dose account for future activities.

3. Applications

Two examples of applications are given in this section. A short description is given on how the results of the planning tool helped in the ALARA-decision process in each case.

The VISIPLAN ALARA planning tool was first applied to perform dose prognoses for the decommissioning activities at the BR3 reactor at the SCK•CEN [2]. A dose assessment was made for activities near the primary circuit. The VISIPLAN model of the working area is displayed in the following figure and covers a cylindrical volume with 7 m radius and 14 m height.

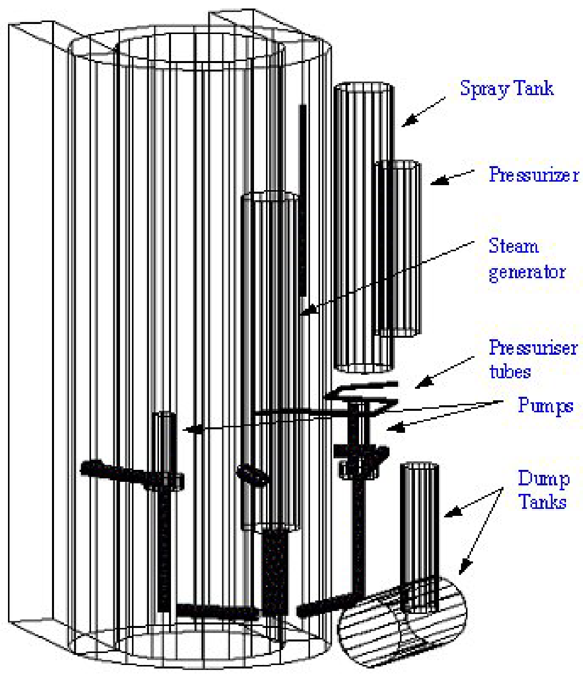

Figure 2. Geometry model used for the work analysis at the BR3 decommissioning site.

Operations were planned on the different levels in the reactor building. The environment is characterised by sources located in the different structures of the building such as the steamgenerator, pressuriser, pressuriser tubes,.....The source strengths were estimated based on the combination of a dose mapping and source inference technique. The analysis of the radiation field helped us to pinpoint the sources with a large contribution to the dose for the planned operations. By adapting the model we were able to study different options in order to reduce the dose for further work. These options involved shielding but also the reduction of the contamination in pressuriser pipes through chemical cleaning.

The program was also applied for the dose assessment for the sampling activities at the target room of a linear accelerator. The working area covered a rectangular area of 6 by 14 m.

No information was available for the multiple sources present in the target room. The source strengths were estimated, with the source inference technique available in the software, based on a detailed dose mapping of the target room and information on the location of the main sources. The sources were located on or near the beam tube (the central pipe section in Fig. 3).

From the resulting source strengths we calculated the radiation field for an unshielded and a shielded situation. The effect of the shielding by lead plates (thickness 0.5 cm) and a lead mat around the beam tube (thickness 1.6 cm) is represented in Fig. 3 together with the unshielded situation. The figures are shown to give the reader a general view of the radiation field in both cases.

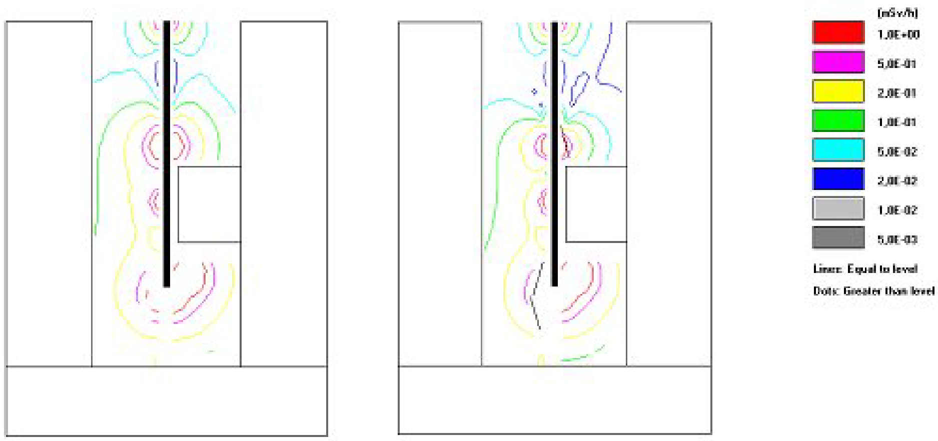

Figure 3. The dose rate distribution for the unshielded and shielded sources. The lead shields, of 0.5 cm are placed in the middle and at the end of the beam tube. The isodoselines go down from 1 mSv/h to 0.005 mSv/h with the intermediate levels given in the figure. The dose rate is the highest near the beam tube.

A series of activities were planned on different locations in the target room. The trajectory containing these tasks is described in Fig. 4. and table I. A set of geometry's was prepared with different shield thickness in order to study its influence on accumulated dose for the defined trajectory. The results are given in Table I.

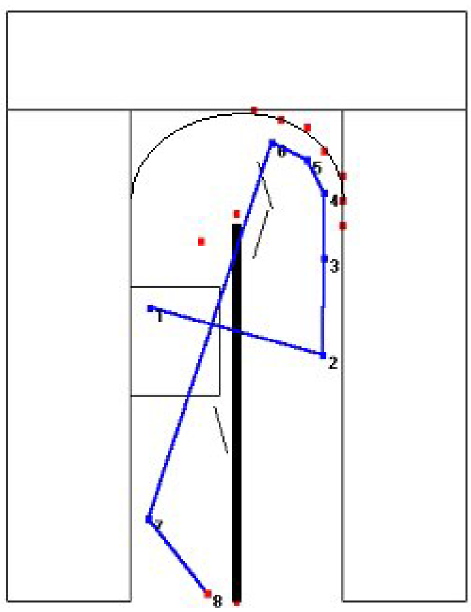

Figure 4. Position of the different tasks in the target room.

TABLE I. COMPARISON OF THE ACQUIRED DOSE ON A TRAJECTORY FOR DIFFERENT SHIELDING THICKNESS

Position	work duration (min)	Calculated dose no shielding (mSv)	Calculated dose .5 cm Pb-plates (mSv)	Calculated dose 1 cm Pb-plates (mSv)	Calculated dose 2.5 cm Pb-plates (mSv)	Calculated dose 5 cm Pb-plates (mSv)
A (1)	60	0.120	0.110	0.110	0.110	0.110
B (2)	120	0.220	0.180	0.180	0.150	0.140
C (3)	60	0.130	0.120	0.110	0.077	0.038
D (4)	60	0.130	0.130	0.120	0.079	0.035
E (5)	60	0.130	0.130	0.120	0.078	0.030
F (6)	240	0.570	0.590	0.510	0.230	0.050
G (7)	90	0.070	0.041	0.037	0.031	0.027
H (8)	90	0.180	0.180	0.180	0.180	0.180
Sum	780	1.55	1.48	1.37	0.935	0.610

It is clear from the table that the highest shield thickness leads to an avoided dose of 0.94 mSv for the tasks on the trajectory.

However a further analysis of the work planning also involved calculations of the dose account during the placement of the shielding. This was done by simulating the work in sequential geometry's describing the situation at different time steps with parts of the final shielding solution in place. From the complete analysis it became clear that the dose invested for the placement of the shielding would be greater then or comparable with the dose reduction for the trajectory of table 1. This suggests that the placement of the shielding only becomes worthwhile when further workloads, besides the given trajectory, are foreseen in the target room.

The predicted values for the accumulated dose were compared with the measured ones. An agreement was found within 30%.

In both cases the VISIPLAN software contributed to the ALARA decision-process by performing a dose account in a structured way. Not only the planned but also the preparatory tasks such as shield placement or chemical cleaning can be taken into account before deciding on the final work plan.

4. Conclusion

The planning and the dose prognoses for a work in a radiative environment involves the handling of an amount of data concerning geometry, materials, source distribution and work organisation. In order to streamline this information we developed the PC-based VISIPLAN ALARA planning tool. The use of a graphical interface for the dose rate representation and for the work definition allows a straightforward approach towards an ALARA work planning. Different work scenarios can be investigated, evaluated and documented in a short period of time. The program has been applied with success for different application such as dose prognoses for routine work and dose prognoses for decommissioning activities.

References

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[2] MASSAUT, V., DEBOODT, P., VERMEERSCH, F., LEFÉBVRE, A. KLEIN, M., "Optimisation and decommissioning: Challenge and limits", 1st European ALARA Network Workshop, ALARA & Decommissioning, 1-3 December 1997, INSTN Saclay France, Paper No 1

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