THE COMBINED USE OF 3D DOSE ASSESSMENT AND HUMAN MOTION SIMULATION IN ALARA D&D PROBLEMS

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Abstract

Operations in a D&D environment are in most cases one of a kind meaning that return of experience is only marginally available for some operations. The problem of being confronted with new environments, operations and risks can be partly solved by the use of a 3D simulation tools combining dose assessment and human motion simulation.

This presentation will show how a combined use of a 3D dose assessment program and the human motion simulation of the work in a virtual environment can help in the evaluations of D&D ALARA problems. An integrated approach to the ALARA assessment will be given including site characterization, human motion simulation, dose assessment and dose optimization.

1. Introduction

Preparing the planning of activities in a nuclear environment involves the technical description of the work but also the assessment of the dose uptake and optimisation in order to comply with the ALARA requirements. The dose assessment in complex nuclear installations is difficult as it is influenced by the shielding geometry, source distribution and ultimately the work organization. A first step in any pre-job dose analysis is the dose characterization of the work site involving the determination of the radiation field at the worker position. This can be done based on direct measurement at the work place or can be based on a radiological model and simulation of the site.

The first approach is practical for work sites where the source distribution and geometry is relatively fixed during the operation. However the dose evaluation becomes more difficult when geometry and source distribution change during the operations such as in decommissioning activities. In the latter case an appropriate dose assessment can be achieved by using a 3D radiological model of the site able to simulate the consecutive geometry and source changes. In order to do so SCK•CEN developed the VISIPLAN 3D ALARA planning tool to assist the ALARA analyst in the field of dose assessment and optimization [1]. The tool allows making a dose assessment in a 3D environment based on a point-kernel calculation corrected with an infinite media build-up factor. VISIPLAN has in the past years proven to be a valuable tool for the ALARA analyst [2-6]. However before any calculations can start we first need to establish an adequate radio-geometrical model of the work site in VISIPLAN. With an adequate model we mean a model with a level of detail suited for both calculation speed and required accuracy for the dose assessment.

The model must include information on the geometry, materials and on the source type and distribution present on the site. Information on the geometry and materials can be derived from plans and technical information, when plans are lacking we can resort to techniques like laser scanning to establish the geometrical model in a 3D CAD format.

The radiological characterisation of a site is more difficult to achieve. Traditionally this is done using a set of 4π dose measurement at different positions of the site together with spectroscopic analysis of sweeps or samples taken from the sources.

This method can be very tedious and dose consuming for complex industrial environments, especially if little information is available on the geometric extend of the sources.

In recent years equipment like gamma camera's and gamma scanners started appearing on the market enabling an easier, remote localization of sources or hot spot on a site.

In this paper we present a method where we combine the use of gamma scanning and the VISIPLAN tool that allows a fast and adequate characterization of a site for radioprotection purposes. The method is demonstrated on data obtained from an industrial site. The work presented here was performed as part of the VRIMOR European 5th framework program on "Virtual Reality for Inspection, Maintenance, Operation and Repair" where the viability of the integration of different technologies like gamma scanning, geometrical scanning, radio-geometrical modelling and human motion simulation were explored [7-8].

First we will give a short description of the gamma scanning equipment used and introduce the calibration method we developed to analyse the gamma scan with VISIPLAN. Secondly we present the general methodology used to characterise a site. Finally we demonstrate the method in the characterisation of an industrial nuclear site at a nuclear power plant.

2. Gamma scanning equipment and calibration

The gamma scanning is performed using the EDR-scanner develop by CIEMAT (Spain) [7-8]. The scanner is based on the integration of three sensors, a collimated gamma detector a video camera and a laser distance meter. The gamma detector is a Cs(Tl) crystal coupled to a photodiode with an energy threshold in the 150-200 keV range. The detector is located in a stainless steel housing with a lead shielding as can be seen in figure 1.

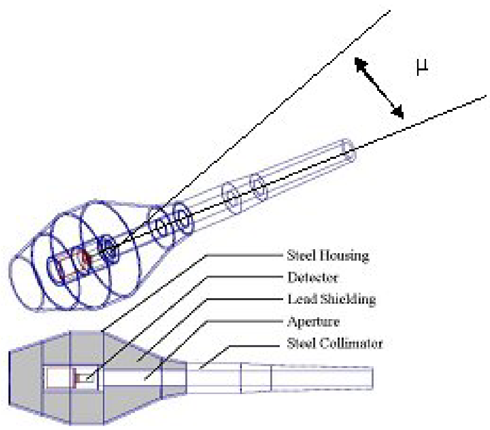

Fig. 1. Layout of the EDR gamma scanner (CIEMAT). μ indicates the angle enclosed by the collimator direction and a point source direction

The effective shielding is about 5 cm lead with a higher shielding in the area surrounding the collimator opening. The collimator aperture used for the measurement is ±4°. The system is mounted on a pan and tilt platform enabling an automatic scan of the area. Spectra are measured in the different detection directions and stored in a 25 energy bin format together with the collimator direction and the distance to the measured object. A special interface is developed to transfer and display the measured results in VISIPLAN.

In order to make the interpretation of the measurements possible within the point-kernel calculation approach of VISIPLAN we need to establish a relationship between the effective dose calculated with VISIPLAN and measurements performed with the EDR scanner. This is done by defining an instrument dose rate and relating it to the effective dose rate. The calibration based on this approach leads to an instrument response function dependent on the energy of the photons detected and on the angle μ between the source and the collimator direction. The directional sensitivity of the detector-collimator couple was measured for a Co-60 and a Cs-137 source at a distance large enough to generate a plan-parallel radiation field at the detector position.

A detailed geometric scan is performed using the "Imager 5003" laser scanner from Z+F ltd before the gamma scan, in order to create a CAD model of the site that can be transferred to VISIPLAN. The distance and orientation data of the EDR-scanner are fitted to the detailed data of the geometry scan in order to determine the EDR position in the CAD, respectively VISIPLAN model.

3. Gamma scan interpretation and model building

The radio- geometric model is established in four steps. In the first step we build the geometry and materials model. In the second we concentrate on finding the most probable source geometry and distribution of the sources. In the third we concentrate on establishing the isotope vector for the source and in the final step we perform a source strength fitting in order to assess the source activity.

The geometric parameters of the model are derived from the detailed CAD plan based on the laser scanning measurements of the work site. These parameters describe a set of primitive volumes that are enriched further with materials information to enable the attenuation calculations.

The source geometry is derived through the interpretation of different gamma scans taken from different locations and historic and technical information of the site. The scans taken from different location allow in most cases to triangulate the positions of the sources or hotspots and reduce the possibility of misinterpretation of such as two consecutive sources on the same line-of-sight to the detector. The suggested source geometry is entered in the VISIPLAN model and enriched with isotopic information.

The isotopic characterization of the sources is performed through the analysis of the spectra of the scan. When available information gathered from detailed spectra taken from sweeps and samples of the sources are also used to detail the isotope vector.

The source strengths are determined by fitting the simulated gamma scan expressed in instrument dose rate values to the measured one. The simulated scan is calculated taking into account the geometry material and source information and the energy dependent directional dose response function of the EDR scanner.

This methodology was first tested in a controlled environment consisting of two well known sources. The method performed well and was able to determine the source strengths within 20 and 30%.

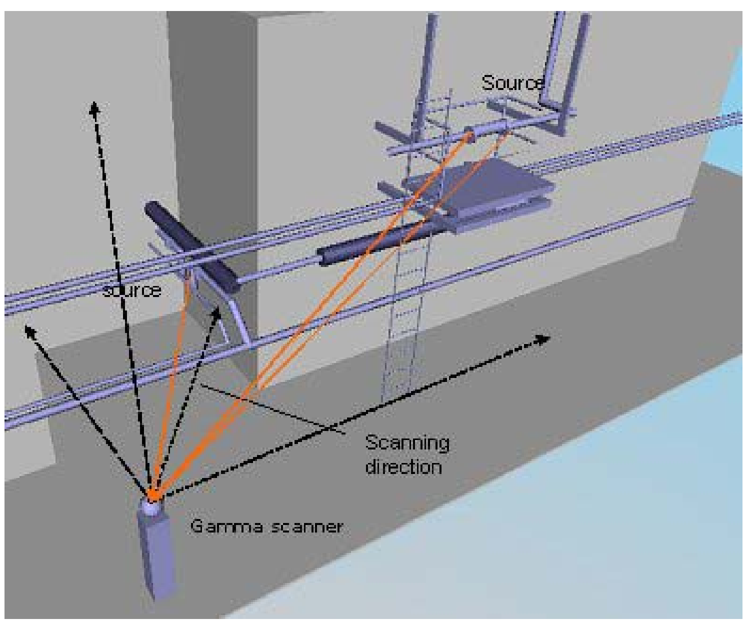

Fig. 2. Gamma scanning of an area involves spectral and distance measurements in the different directions

4. Demonstration of the method in an industrial site

A demonstration of the method was performed within the VRIMOR project. The industrial area selected was in the auxiliary building of Almaraz Nuclear Power Plant (Spain) [8].

A geometric scan of the area was performed by Z+F Ltd followed by a gamma scanning campaign performed by the CIEMAT team. The results of the geometric scan and the model derived from it in VISIPLAN are given in figure 3. The materials data associated to the primitive volumes were gathered on-site by Tecnatom.

A hot spot was found at the end flange of a tube. This source is confirmed in a second scan taken from another position. This information together with the technical information gathered by Tecnatom on the site lead us to simulate the area using three cylindrical volumes representing the source A, B and C in the tubes (fig. 3.).

The spectral analysis of the measurements suggests that Co-60 is the pre-dominant isotope, so it was decided to continue the analysis with Co-60 equivalent sources.

Based on this model we determined the source strength of the A, B and C sources. A good agreement was found between the simulated and the measured gamma scans.

Based on the determined source strengths we could now calculate the dose in the area with the VISIPLAN tool and compare the doses with 4π measurements on site.

An agreement was found within 20 to 30 %, a good agreement considering the accuracy of the calculation method used in VISIPLAN and the gamma scan calibration method proposed for the gamma scan interpretation.

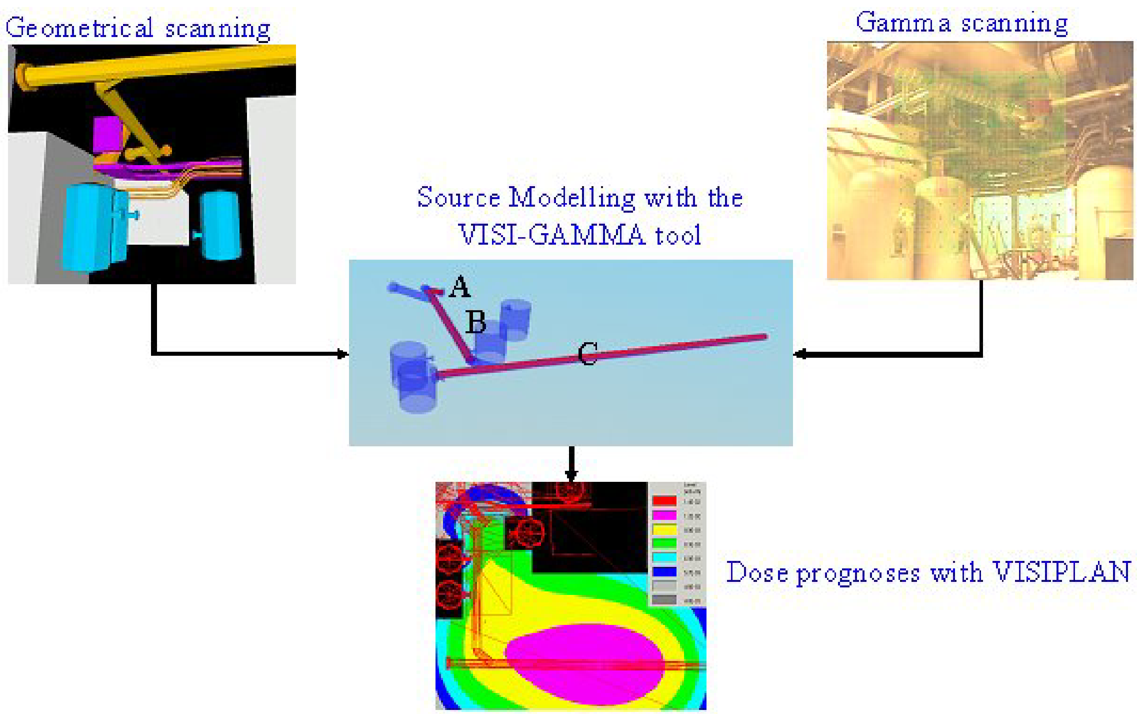

Fig. 3. Method of characterising an unknown site

5. Human motion simulation tools

The established 3D model of the environment containing source, geometry and materials information can now be used in the assessment of the task dose.

In order to do so we first need to define the different work trajectories in the environment. The geometric model used for the site characterization can now be used in human modeling tools such as ErgoDose, developed by NNC Ltd and HeSPI developed by UPM during the VRIMOR project.

These tools provide an ergonomic and fast way to simulate the different tasks that are to be performed in the work area. The first modeling tool uses a SpaceMouse driven interface while the second is based on a voice driven interface to direct the movements of the mannequin.

The human motion simulation results in a detailed trajectory of the hands, chest and head that are then imported in the VISIPLAN 3D ALARA tool to assess the dose for the different tasks.

The trajectories can be assessed for different shielding solution by adapting the model in VISIPLAN this in order to evaluate shielding effectiveness in reducing the task dose. This method enables the user to select the best approach to perform the task in compliance with the ALARA considerations.

The human motion simulation tools combined with the environment and dose read outs allow an improved communication on the radiation risk present at the work place.

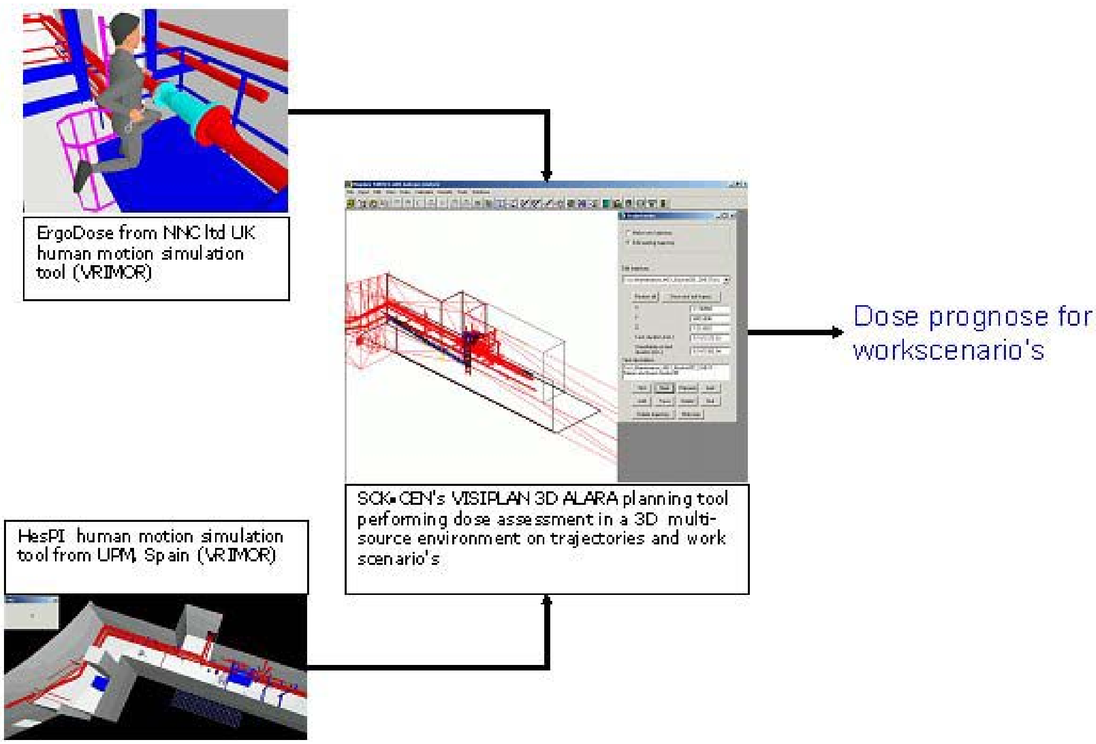

Fig. 4. Human simulation tools are used to generate detailed trajectory for dose assessment with VISIPLAN

6. Conclusions

A methodology is developed to establish an adequate radiological model of a work site based on the integrated approach using gamma scanning, geometrical scanning and radio-geometrical modelling using the VISIPLAN 3D ALARA planning tool. The method is successfully demonstrated in the characterisation of an industrial environment.

Using this method dose can be avoided due to the remote nature of the gamma scanning but also in the job planning through a better knowledge of the work environment based on the 3D radio-geometrical modelling of the site.

The combination of the radio-geometrical and the human modeling tools provides the ALARA analyst with a state of the art dose assessment and dose optimization tool [10].

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