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Quantification of the Distribution of Radiation Doses Received by Humans through the Various Pathways in a Contaminated Indoor Environment

(INDOOR DOSE)

Final report (summary)

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1. Objectives

The primary project objective was to develop a model methodology that can be used to evaluate the significance of each of the different contributions to radiation dose that would be received in the indoor environment after an airborne radioactive contamination of some sort has occurred. It was clear from previous work carried out by the same workers that the currently available data would not be sufficient to allow adequately detailed modelling of these dose contributions. Therefore, a suite of experimental investigations were planned in connection with the project work.

In relation to dose assessments after airborne releases, particularly the dose contributions from deposition of contaminants on the human body have in the past largely been ignored. In those few cases, where such doses are considered (e.g. in the European standard risk assessment model COSYMA), the level of detail was clearly inadequate. For instance, deposition velocity to and clearance from humans are in COSYMA both assigned one standard value for all aerosol, which the work of the project partners has shown to be inappropriate. Recent investigations showed that both beta and gamma doses from deposition on humans could at least in some cases be highly significant. It was therefore an objective of the INDOOR DOSE project to address this shortcoming by identifying model methodologies and parameter ranges that would allow detailed estimation of the doses from contamination of humans.

It was also envisaged that theoretical/computational investigations of photon transport through complex structures in the indoor environment would be called for, to evaluate doses properly.

It was a specific project objective to gain sufficient level of model methodology and parameter detail to facilitate evaluation of the importance of the differences between various contaminating scenario types. For instance, the contamination might be of outdoor origin, but have significant implications for people staying indoors, as would be the case in connection with a large accident at a nuclear installation. It might, however, also arise from events that would be likely to be of more locally affecting nature, such as the detonation of a so-called 'dirty bomb' radioactivity dispersion device. It could also be that the source was constituted by a spillage, e.g. in the indoor working environment.

It was decided to focus on one type of contamination scenario, which would be applied to demonstrate the developed methodology in an example. In addition, considerations were to be made of how other scenarios could be evaluated using essentially the same methodology.

2. Brief description of the research performed and methods/approach adopted

The experimental investigations were carried out under three work packages: one dealing with issues relating to the deposition of contaminant aerosols and gases on the surfaces of humans, the second with the natural processes of clearance of and penetration through the skin, and the third with redistribution of deposited contaminants in the indoor environment.

WP 1. Contaminant deposition to skin and clothing

A series of investigations were made to identify the significance of physical parameters that could influence the deposition. A main tool was here a previously developed sampling technique involving neutron activation analysis of tracer labelled particles.

For instance, measurements of tribo-electric potentials and electric fields in the indoor environment in connection with experiments to assess the deposition of various aerosols to humans revealed that in the vicinity of TV sets, the high electric field can lead to very significant deviations in the pattern of submicron particle deposition to humans.

Heat sources in the indoor environment may result in convective turbulent currents, but other influences of heat sources (e.g. thermo-phoresis) were found to be practically without importance. However, other factors, such as skin moisture and physical movement of the test persons in the room, were found to correlate clearly with the deposition velocity of both sub- and super-micron particles.

The database of deposition velocities to hair was improved considerably through new experimental work. Also, the hair strands were here sectioned to allow determination of contamination levels on inner and outer hair parts. This has an important bearing on beta doses from hair contamination.

As preliminary work had indicated that elemental iodine could well play a key role in determining the doses from deposition to humans after a major nuclear power plant accident, experiments were dedicated to the examination of elemental iodine deposition to skin. This was done in a specially constructed exposure chamber, using live hairless rats. The results are the first of their kind and confirmed that the deposition velocity was high, as had been inferred from experimental work on other types of surface.

Experiments were made in a wind-tunnel to determine the influences that outdoor wind conditions would be likely to have on the deposition process. As expected, increases in wind speed were found to lead to significant increases in particle deposition to skin.

WP 2. Clearance and penetration of contaminants deposited to humans

A specially designed fluorescence scanning system was used to examine the natural clearance rates of various types of contaminant aerosol on humans. Particles in the > 2 μm range were generally found to have very short half-lives on human skin (hours-days), whereas particles in the 1 μm range appear to remain on the skin until it sheds from the surface of the body.

Using in vitro techniques employing a confocal microscope for particle visualisation, the effects of particle penetration into skin pores and hair follicles were studied. In these experiments, no particle penetration through the epidermis was recorded.

A methodology was developed for examination of the influence of particle constituents and solubility on the penetrability.

The penetration of aerosol through clothing and onto skin was examined by neutron activation of tracer-exposed samples and found to be of very little, if any, significance.

WP 3. Redistribution of indoor contaminants

In the context of re-suspended indoor contaminant particles, experiments have been conducted to determine the changes that occur in the size distribution of the deposited contaminant particles and the bearing that this has on the deposition to humans of the subsequently re-suspended particles.

In other experiments, the focus was on determining re-suspension factors from realistic mechanical impact in the indoor environment. Furthermore, a series of experiments have been carried out to determine the relative importance of the various body surfaces in contributing to elevated breathing zone concentrations of contaminants.

Another mechanism that may be responsible for indoor contaminant redistribution is contact transfer. A series of measurements showed that this mechanism is significant even for small particles in the 0.1 μm range. Surface moisture generally enhances transfer, and the transfer to dry gloves was found to vary considerably according to the material characteristics of the contaminated surface.

WP 4. Dosimetric modelling

The fourth work package employed the experimental results together with available information from the literature and theoretical investigations, for instance of the photon transport in a contaminated indoor environment, to establish a methodology for calculation of doses from contamination on humans and on indoor surfaces, as well as from inhalation of contaminants and contact transfer of contaminants from surfaces to humans.

An example was used to illustrate the methodology in relation to a situation involving a large nuclear power plant accident. In this case, doses from deposition on both skin and indoor surfaces, as well as from inhalation, proved significant. Re-suspension and contact transfer were found to generally play a less significant role in connection with accident scenarios of the modelled type. However, in other perceivable contamination scenarios, also these may be important to consider. Generally, elemental iodine and the radio-caesium isotopes contribute most to the doses received in the scenario.

3. Main achievements (absolute and relative to expectations)

The overall goal of the project was to establish a model methodology for detailed estimation of doses received in a contaminated indoor environment. This goal has been achieved. The methodology is applicable in forming more detailed modules for the assessment of implications of indoor contamination in European standard models for nuclear accident consequence assessment.

It was possible to achieve this goal through the experimental derivation of a series of datasets and experiences of other nature within the project. The different datasets add significant contributions to the general state of knowledge of the behaviour of aerosols and gases in the indoor environment and their deposition and natural removal from humans. These achievements will thus have wide impact also outside the nuclear research and end-user communities.

Many of the findings can be applied in models on health effects associated with air pollution in both the occupational and non-occupational sector.

4. Exploitation and dissemination

The integration/implementation of project findings in European standard models is envisaged under the Sixth Euratom Framework Programme.

The outputs of INDOOR DOSE were disseminated at the NKS supported Nordic Conference on Urban Contamination at Risø, 7-9 May 2003. A key feature was here to pinpoint the importance of improving data and methods applied in decision support models. Leading modellers and end-users in the field participated in the conference. A total of four related papers over presentations given at the conference have been submitted for publication in a special issue of the Elsevier *Journal of Radioactivity*. The peer-reviewing process is ongoing.

Project results are also being disseminated through other journal and conference publications by the consortium. For instance, results have been presented orally at the 9th International Conference on Indoor Air Quality and Climate in Monterey, California, 30 June to 5 July 2002, and at the British Occupational Hygiene Society Conference (BOHS), Imperial College, London, 8-10 April 2003. Posters were presented at *Perspectives in Percutaneous Penetration*, Antibes, France, 2-6 April 2002, and ENVIRON 2003, Irish Environmental Researchers Colloquium in Galway, Ireland, 7-9 January 2003.

It is planned that the developed methodology will also be used to establish IAEA's recommendations in this context in a new Safety Standard book (IAEA NS-44) on intervention criteria in a nuclear or radiation emergency.