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TRAINING COURSE ON WORKPLACE MONITORING

INTRODUCTION

OBJECTIVES OF THE TRAINING PROGRAMME

OBJECTIVES

To strengthen the radiation protection programme in Member states by assisting in establishing workplace monitoring programme by providing insights on;

- Background and significance of monitoring.
- Techniques applied for monitoring,
- Instruments employed for monitoring,
- Demonstrating the practical use of instruments and interpretation of results,
- Calibration and Quality considerations.

STRUCTURE OF THE TRAINING

The training course on workplace monitoring contains three modules:

Module 1 pertains to Radiation Dose Rates (X, gamma, beta and neutron) and Surface Contamination Monitoring.

- ❑ There are 6 lessons in this module.

Module 2 pertains to airborne contamination monitoring and noble gas, iodine, tritium monitoring and specific workplace applications.

- ❑ There are 6 lessons in this module.

Module 3 pertains to practical exercises and demonstrations.

- ❑ There are 5 practical lessons in this module.

Module 1: Fundamentals of Radiation Monitoring

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CONTENTS

Module 2: Airborne Contamination and Specific Applications

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CONTENTS

MODULE 3: Practical Lessons

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CONTENTS

- ❑ Practical 1: Workplace Monitoring
  - Design of a Monitoring Program
  - Preparation/Review of Documentation
- ❑ Practical 2: Dose Rate Monitoring
  - The selection and use of radiation survey instruments for gamma and neutron measurements

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CONTENTS

- Practical 3: Surface Contamination Monitoring
  - The selection and use of alpha and beta contamination monitors and counting systems
  - Calculation of results from measurements
  - Counting statistics and the impact on results

MODULE 3: Practical Lessons

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CONTENTS

- ❑ Practical 4: Workplace monitoring
  - Performance of surveys using dose rate meters, surface contamination monitors for direct measurements and wipe testing, including liquid scintillation counting
  - Monitoring follow up to contamination and radiological incidents

MODULE 3: Practical Lessons

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CONTENTS

- Practical 5: Airborne Monitoring and Spectrometry
  - Airborne contamination monitoring using portable air samplers and fixed air monitors.
  - Alpha spectrometry discussion/demonstration
  - Gamma spectrometry using NaI scintillation detectors and hyperpure germanium (HPGe) – discussion/demonstration

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LESSON 1:
BASIC CONCEPTS OF WORKPLACE MONITORING– PART 1

LESSON 1: BASIC CONCEPTS- I

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Introduction

Purpose of Workplace Monitoring

Designing the Monitoring Programme

- Operational Quantities for External Radiation
- Fingerprints
- Types of Monitoring
- Frequency and Location of Monitoring

INTRODUCTION

INTRODUCTION

Ionising radiations have the potential to harm human body if exposed to excessive levels

Occupational exposures are associated with various activities of the nuclear fuel cycle

A framework of radiation protection is established

- To limit exposure
- To optimise protection within these limits.

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Reliable measurements of radiation exposures from radioactive materials are essential

- to demonstrate compliance with regulatory limits
- to allow optimisation of working conditions
- to identify any failures or breakdown in control

The general term “monitoring” describes measurements related to identification, quantification and control of exposure due to radiation and radioactive material.

- Monitoring is more comprehensive than simple measurement.
- It comprises both assessment and interpretation.

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Workplace monitoring (WPM)

- comprises measurements made in the working environment

Individual monitoring (IM)

- monitoring by equipment worn by individual workers or measurement of quantities of radioactive material invivo or invitro and the interpretation of such measurements.

INTRODUCTION

From experience it has been seen that:

- Sometimes only WPM is necessary and/or possible
- Sometimes only individual monitoring is necessary
- Normally both are necessary and possible

As an Agency guideline, if potential for committed effective dose could exceed 1 mSv/year then IM should be considered.

WPM could be made below 1 mSv/year for confirmatory reasons in supervised area.

PURPOSE OF WORKPLACE MONITORING

PURPOSE OF WORKPLACE MONITORING

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- Monitoring may be part of the prior radiological assessment

- Determination of whether radiological exposures in the workplace are under adequate control or whether operational changes have improved or worsened the situation.

  - These measurements facilitate the control of exposure of workers by early detection of deteriorating or abnormal conditions, thereby allowing appropriate remedial actions.

PURPOSE OF WORKPLACE MONITORING

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- Selection of appropriate personal protective equipment
- Assistance in preventing the spread of contamination
- Provision of information that can be used to allow workers to understand how, when and where they are exposed and to motivate them to reduce their exposure.

PURPOSE OF WORKPLACE MONITORING

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- Demonstration of good working practices and engineering controls (e.g. the adequacy of supervision, training, etc.)
- Detection of failures of containment or departures from good operating procedures
- Classification of controlled and supervised areas.
- Provision of a prompt and reliable alert to allow workers to evacuate to a place of safety

PURPOSE OF WORKPLACE MONITORING

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- Contribution to the dose assessment or estimation for individual or groups of workers and demonstration of compliance with dose constraints

- Provision of information for
  - The planning of programmes of individual monitoring
  - Defining operational procedures and facilities
  - Evaluation of doses in the event of accidental exposures

DESIGNING THE MONITORING WORKPLACE

DESIGNING THE MONITORING PROGRAM

- The Basic Safety Standard states that the type and frequency of workplace monitoring shall be based on:

  - Expected fluctuations of:
    - Dose rate, Surface contamination,
    - Activity concentrations in air

  - The likelihood and magnitude of exposures in anticipated occupational occurrences and accident conditions

REQUIREMENTS OF MONITORING PROGRAM

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- According to BSS(2014), the monitoring programme should;
  - Specify the quantities to be measured.
  - Identify the most appropriate measurement methods.
  - Outline the procedures to be adopted.
  - Recommend the frequency of monitoring and monitoring points.
  - Stipulate the reference levels and actions to be taken if these levels are exceeded.

OPERATIONAL QUANTITIES

NEED FOR OPERATIONAL QUANTITIES

Operational quantities are needed for monitoring external exposures because:

- ❑ The protection quantities generally are not measurable,
- ❑ exposure limits are given in terms of protection quantities.
- ❑ for area monitoring a point quantity is needed
  - ○ Quantities are defined by ICRU-86,88,92

EXTERNAL RADIATION

- For the purpose of area monitoring ambient dose equivalent H*(d) for gamma radiation and the directional dose equivalent H'(d,Ω) for beta gamma radiation are defined. H'(3,Ω) for dose equivalent to the eye.
- The units of effective and equivalent dose are based on these measurement values
- It is good practice to have all monitors at the workplace using the same quantities

The ambient dose equivalent at a point in a radiation field is the dose equivalent that would be produced by the corresponding expanded and aligned field in the ICRU sphere (30 cm diameter tissue) at a depth ‘d’, on the radius opposing the direction of the aligned field. The recommended value of ‘d’ for penetrating radiation is 10mm.

EXTERNAL RADIATION

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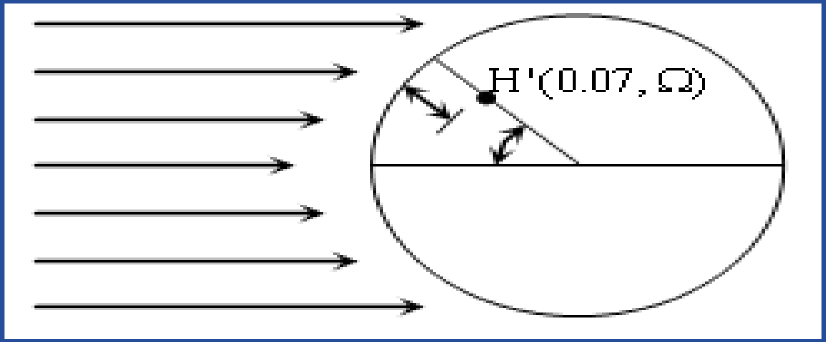
- Primary standards for ambient and directional dose equivalent, H*(d) and H´(d), do not exist.

- Reference fields for calibration of instruments are usually realised in terms of
  - radiation fluence rate, Ǿ, (for neutrons)
  - air kerma rate, K_a , (for photons) ,
  - absorbed dose to tissue (electrons),
  - and the application of fluence-(or air kerma or tissue absorbed dose) to-dose equivalent conversion coefficients.

EXTERNAL RADIATION – H’ (0.07)

- Directional Dose Equivalent, H′(0.07), expressed in Sv, is the dose equivalent at a depth of 0.07 mm in a similar sphere, and is the quantity used to control dose equivalent to skin.



- H′(0.07) is most important for weakly penetrating radiation, generally β radiation and low energy x and γ radiation, although penetrating radiations also contribute if present

- The unit of H’(0.07) is the Sievert or sieverts/hour.

SURFACE CONTAMINATION

- Surface contamination is the ratio between the activity of the radionuclides present on a surface to the area of the surface.
- Surface contamination is given in terms of “activity per unit area” (expressed in Bq/cm^2)
- For contamination monitoring, the instrument typically reads in counts per minute and has to be converted to the operational unit based on the efficiency of the instrument, either the area of the instrument (for direct monitoring) or the area wiped (for loose contamination monitoring), the kind of material/surface and contamination.

AIRBORNE CONTAMINATION

- Airborne activity is the ratio between the activity of the radionuclides in the air and the volume of the air
- Airborne activity is given in terms of “activity per unit volume” (expressed in Bq/m^3)
- Airborne activity is typically measured in units of activity and then has to be converted to the operational unit using the efficiency of the detector and the volume of air sampled

DERIVED QUANTITIES

EXTERNAL RADIATION

- The operational quantities - gamma or beta gamma radiation dose rate – can be directly related to occupational exposure through time

- An acceptable occupational radiation dose rate can also be derived for comparison with the measured dose rate
  - e.g. 2.5 μSv/h for 2000h gives rise to 5 mSv annual exposure

SURFACE CONANIMATION

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- The operational quantity of surface contamination cannot be directly related to occupational exposure.

- A relationship between surface contamination and occupational exposure can be derived making assumptions about the radionuclide, route and duration of exposure.

SURFACE CONAMINATION

- An acceptable derived surface contamination level can be derived for comparison with the measured level.

- More typically today, generic derived surface contamination levels are used
  - DWL for beta, gamma 0.4Bq/cm^2 and 0.04 Bq/cm^2 for alpha surface contamination in transport regulations
  - More recently, radionuclide specific contamination levels have also been derived.

AIRBORNE CONAMINATION

- The operational quantity of airborne contamination cannot be directly related to occupational exposure.
  - Can derive a relationship

- Limit of intake is the intake of exposure to a single radionuclide (in Bq) of a specific physical and chemical form which would result in the annual committed effective dose limit.

AIRBORNE CONAMINATION

An acceptable airborne contamination level can then be derived for a specific radionuclide in a specific chemical form for comparison with the measured level.

- For example, Derived Air Concentrations (DAC)

$$DAC\ in\ Bq/m^3 = \frac{Limit\ on\ Intake\ of\ Activity\ (Bq)}{2000h\ x\ 1.2\ m^3\ /h}$$

AIRBORNE CONANIMATION

- Airborne contamination can then be expressed as DAC fractions which correspond to fractions of Limits on Intake if breathed for a year.
  - e.g. 0.3 DAC would result in 0.3 of an annual dose limit if breathed for a year
- An estimate of intake can also be made in DAC-h by multiplying the fraction of DAC by the time of exposure.
  - 2000 DAC-h results in annual dose limit

FINGERPRINTS

- Most facilities handle a range of radionuclides.
- In order to assess surface contamination or airborne activity, the nuclides present and their relative activity concentrations are required to be known.
- This is called a fingerprint or nuclide vector
- The fingerprint is used to help identify the workplace monitoring requirements and interpretation of results.

FINGERPRINTS

Fingerprints may be determined from the following sources of information:

- Safety report based on Modelling codes (irradiation of nuclear fuel in a neutron flux).
- Operational history of the facility.
- Radiochemical analysis of representative samples of the radioactive material.
- Prior radiological safety assessmen.t
- A combination of the above.

FREQUENCY AND LOCATION OF MONITORING

TYPES OF MONITORING

The type of monitoring (related to the purpose) is required to be known to determine the frequency and location.

Monitoring is classified into:

- Routine
- Task Related
- Special Monitoring
- Confirmatory Monitoring

TYPES OF MONITORING

Routine monitoring is:

- Intended to verify the suitability of continuing operations
- Intended to demonstrate that the working conditions remain satisfactory and meet regulatory requirements

ROUTINE-EXTERNAL RADIATION

Typically a network of monitoring points will be established as a routine monitoring regime. Focus locations on:

- High occupancy
- Boundaries of controlled areas
- Expected operational activities
- High dose rates
- Where dose rates are liable to change
- Which would indicate early failure of equipment or process condition changes

ROUTINE-EXTERNAL RADIATION

Frequency depends on occupancy and likelihood of change

- Where no substantial change expected and low occupancy, frequency can be low, e.g. monthly.
- Where no substantial change and occupancy high, or some change and low occupancy, then typical frequency would be weekly or daily.
- When sudden increases in dose rate may occur, or a worker may be significantly exposed then dose rates may require continuous monitoring.

ROUTINE - SURFACE CONTAMINATION

Removable contamination is more typically monitored as it can affect occupational exposure or loss of control of contamination. Focus locations on:

- High traffic or high occupancy areas, boundaries of controlled areas and work areas
  - Larger wipes more frequently for control
  - Spot check with smaller wipes to confirm absence of contamination
  - Direct monitoring of touch points or at lower frequency
- Areas less likely to be contaminated
  - Use small wipes and direct monitoring

ROUTINE - SURFACE CONTAMINATION

- Frequency of loose contamination monitoring is typically high.

  - High risk areas monitored daily
  - Lower risk areas monitored weekly or monthly
  - Very low risk areas monitored every 3 or 6 months or annually – typically this frequency is associated with direct monitoring.

- Mix high frequency of loose contamination with lower frequency of direct in same area.

ROUTINE - AIRBORNE CONTAMINATION

- All potential airborne sources should be identified whether from routine or accidental conditions
- Migration routes from potential sources should be identified
- Identify potential exposure of personnel in terms of annual intake and decide whether continuous monitoring is required or sampling
  - If greater than annual limit do continuous sampling
  - If < 0.02 annual limit, then sampling not necessary

ROUTINE - AIRBORNE CONTAMINATION

Airborne monitoring locations chosen:

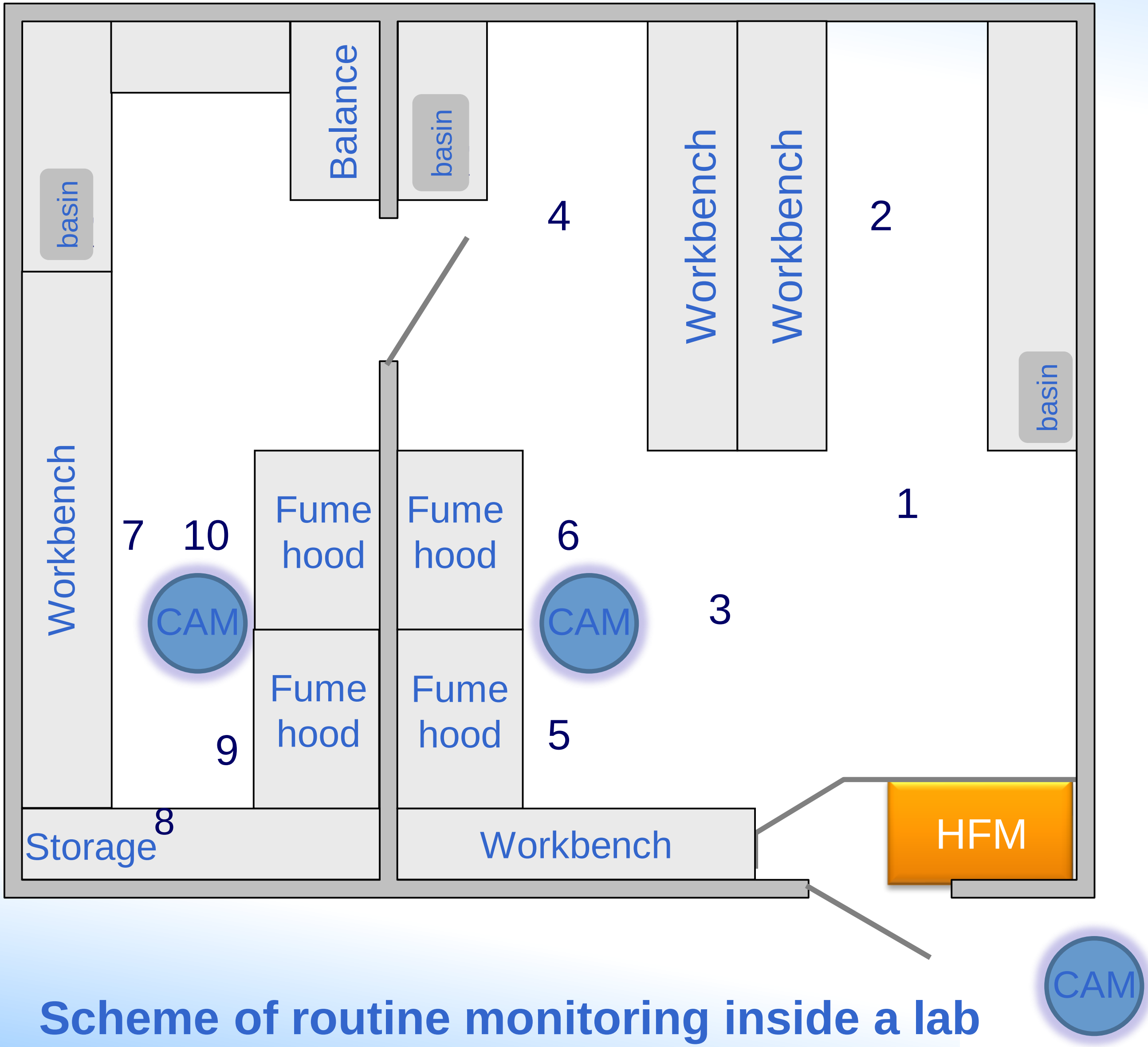
- To provide alert with least delay from onset of release – monitor as close as practical to a potential release, but also use secondary method (e.g. stack or further distance from source).
- To monitor migration pathways.
- Considering ergonomics, practicality, air flow patterns.
- Away from vents, inlets, doors and heat sources.
- Where necessary remotely.
- For installations, use fixed location samplers.

EXAMPLES OF ROUTINE MONITORING

Frequency of airborne monitoring is typically high, depending on the potential airborne exposure and occupancy of the area. Typical frequencies are:

- Continuously
- Once per shift
- Daily
- Weekly

ROUTINE – WORKPLACE MONITORING



Scheme of routine monitoring inside a lab

TYPES OF MONITORING

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Task related monitoring

Conducted during a specific operation/task, provides data to support the immediate decisions on the management of the operation.

Recommended to confirm the predictive estimates of radiological conditions and optimize protection.

Where working conditions change and operations of limited duration (shorter than routine monitoring).

Provides data to support immediate decisions on the operation (establish protective measures).

Complements individual monitoring by providing useful indicators to predict doses.

TASK RELATED MONITORING

The need for task related WPM shall be agreed with the operator and the radiation protection staff

The objectives and methods to be agreed on a case-by-case basis

Investigation levels need to be established, these can differ from routine monitoring

TASK RELATED MONITORING - EXTERNAL

- Locations defined for the operation.
- Use installed monitoring equipment to give warning – could be routed to a control room.
- Outside controlled area to confirm dose rates during tasks are acceptable (e.g. outside of waste build up areas). For beta radiation, could be related to areas where hands may come into contact either before touching or to verify the dose rates.

TASK RELATED MONITORING - CONTAMINATION

- Verify contamination levels as work proceeds and to assist in contamination control.
- Floors adjacent to work areas could be monitored during and after work.
- Tools may also be monitored or gloves.
- Outside of containment before removal from the area.
- For airborne monitoring, may use portable air samplers for the duration of the work activity

EXAMPLES

- Filter change operations
- Non-routine maintenance operations
- Breakdown activities
- Clean-up operations

TASK RELATED MONITORING - EXAMPLE

Decontamination operation carried out in a specially erected tent to ensure prevention of spread of contamination. Airborne contamination monitoring is task related.

TYPES OF MONITORING

Special monitoring:

- Investigative in nature
- Covers a situation where there is inadequate information to demonstrate adequate control
- The WPM programme should define when special monitoring is to be carried out
- The WPM programme should define how and how quickly the results are to be reported, and relevant investigation levels.

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SPECIAL MONITORING

Workplace monitoring is done:

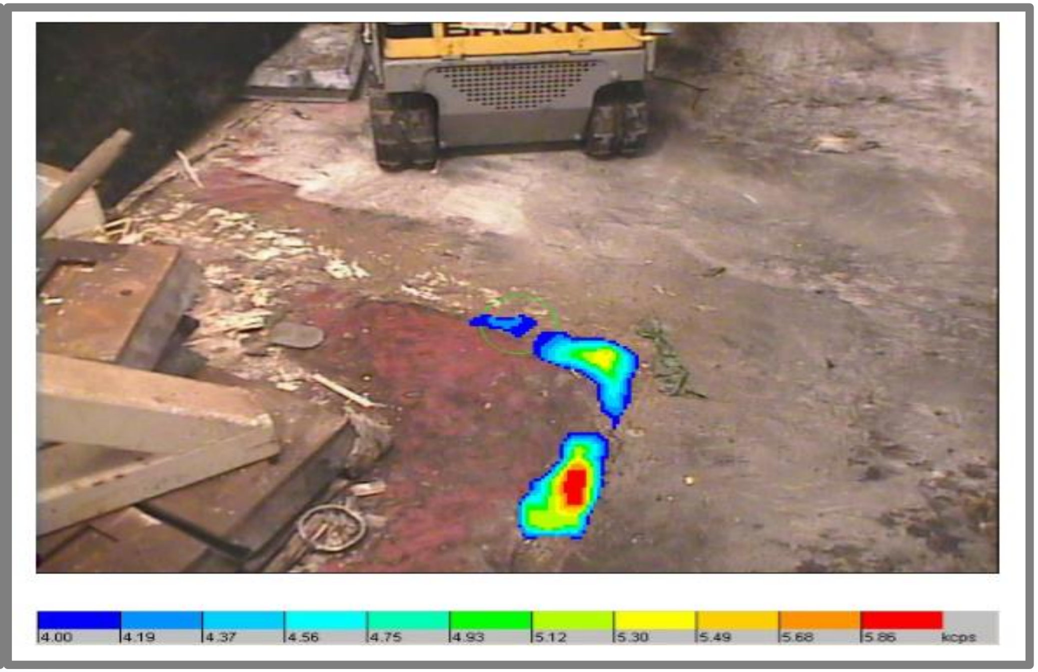
- Prior to the initial use of the radiation installation, or as soon as possible after radiation sources are brought into the area.
- Whenever changes in procedures, equipment, shielding, or sources have occurred.
- Periodically to detect the effect of long-term changes in equipment, environment and work habits.
- When an accident or incident is suspected or after it has occurred.

SPECIAL MONITORING - EXAMPLES

- Commissioning
- Decommisioning
  - Identify gamma hot spots, clearance surveys
- Modifications
  - Identifying where shielding should go or amount
- Abnormal conditions
  - Identify hot spots to prioritize removals
  - Identify man access routes or dose uptake minimization
  - Identify operational challenges, for example blockages
  - Extent of spillage
  - Finding lost sources

SPECIAL MONITORING - EXAMPLES

Example: Hotspot identification using gamma imaging camera.



TYPES OF MONITORING - CONFIRMATORY

Confirmatory monitoring is performed where there is a need to check assumptions made about exposure conditions.

Used to verify the robustness of shielding and other protection measures.

Used, for example, to confirm the effectiveness of protective measures.

SUMMARY

- Workplace monitoring is necessary to identify the potential exposures. It involves measurement of

  - External exposure measurements
  - Surface contamination measurements
  - Air activity monitoring

- Workplace monitoring helps to control the exposure by taking suitable protective measures.