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Monitoring for inadvertent movement and illicit trafficking of radioactive material

Surveillance des mouvements non déclarés et des trafics illicites de matière radioactive

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 22188 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

Introduction

Inadvertent movement and illicit trafficking in radioactive materials[1)] are not a new phenomenon. However, concern has increased remarkably in the last decade. A few percent of these incidents involve so-called “special nuclear materials”, which may be used for nuclear weapons and therefore cause a threat of nuclear proliferation. The vast majority of these incidents, however, involve radioactive sources, low-enriched, natural and depleted uranium, which are not usable for weapons. In the case of inadvertent movements, there have been instances in which loss of control over radioactive materials has led to serious, even fatal, consequences to persons. Examples include unintentional incorporation of radioactive materials into recycled steel, recovery of lost radioactive sources by unsuspecting individuals, and deliberate purloining of radioactive material.

The potential radiological hazard to workers, the general public and the environment, caused by such radioactive materials adds an additional threat to inadvertent movement and illicit trafficking, so both the proliferation threat and the radiological hazard shall be considered. Detection of radioactive materials at border crossings as well as inside countries, i.e. at check points, is therefore an important issue.

This International Standard addresses both the procedural aspects of detecting radioactive materials as well as the minimum requirements regarding instrumentation used in the process. The procedural aspects cover the techniques to search, locate and possibly identify radioactive substances and may be summarized under response activities. Guidelines for appropriate training programs might also be considered a relevant aspect. Instruments used in the process might comprise stationary monitors, portable or hand-held detectors’ and these need to be characterized with respect to minimum requirements in order to make the recommended procedures applicable. Based on the results of an extensive testing program on such detection systems, undertaken in cooperation with the International Atomic Energy Agency (IAEA), test procedures are recommended for routine operation (to ensure operability of equipment) and also for acceptance testing (to verify minimum requirements).

It is assumed that such an International Standard will allow more efficient use and operation of existing equipment, will enhance communication across borders and encourage activities to detect and counteract illicit trafficking in radioactive materials. The benefits thus gained contribute towards the efforts in counter-proliferation and radiation protection. On the contrary, a lack of standardization will delay implementation of intended activities, specifically because certain questions (e.g. investigation level, action threshold) shall be agreed upon internationally. Technical documents published by the IAEA in this subject area are a first step in recommending justifiable and agreed specifications and procedures, see [2], [3] and [4].

1) Since nuclear materials are also radioactive, in this International Standard the term “radioactive materials” always includes nuclear materials.

Monitoring for inadvertent movement and illicit trafficking of radioactive material

1 Scope

This International Standard specifies methods and means of monitoring for inadvertent movement and illicit trafficking of radioactive material. It provides guidelines on the use of both stationary and portable (e.g. hand-held) instruments to monitor for radiation signatures from radioactive material. Emphasis is placed on the operational aspects, i.e. requirements derived for monitoring of traffic and commodities mainly at border-crossing facilities. Although the term border is used repeatedly in this International Standard, it is meant to apply not only to international land borders but also maritime ports, airports, and similar locations where goods or individuals are being checked. This document does not address the issue of detection of radioactive materials at recycling facilities, although it is recognized that transboundary movement of metals for recycling occurs, and that monitoring of scrap metals may be done at the borders of a state.

This International Standard is applicable to regulatory authorities seeking guidance on implementation of action plans to combat illicit trafficking, to law enforcement agencies (e.g. border guards) to obtain guidelines on recommended monitoring procedures, and to equipment manufacturers in order to understand minimum requirements derived from operational necessities according to this International Standard.

NOTE The general term "dose" refers to ambient dose equivalent if not stated otherwise in this International Standard.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60038, *IEC standard voltages*

IEC 60846, *Radiation protection instrumentation — Ambient and/or directional dose equivalent (rate) meters and/or monitors for beta, X and gamma radiation*

IEC 60068-2-1, *Environmental testing — Part 2: Tests — Tests A: Cold*

IEC 60068-2-2, *Environmental testing — Part 2: Tests — Tests B: Dry heat*

IEC 61526, *Radiation protection instrumentation — Measurement of personal dose equivalents* $H_p(10)$ *and* $H_p(0,07)$ *for X, gamma and beta radiations — Direct reading personal dose equivalent and/or dose equivalent rate dosemeters*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
control of radioactive materials
act of maintaining cognizant supervision by proper authorities over the production, use, storage, transport and disposal of radioactive materials

3.2
detection
discovery on the basis of measurements and interpretation of results of a case of inadvertent movement or illicit trafficking

3.3
detection limit
quantity which specifies the minimum sample contribution which can be detected with a given probability of error using the measuring procedure in question

3.4
false-alarm rate
rate of alarms which are not caused by a radioactive source under the specified background conditions

3.5
illicit trafficking
any intentional unauthorized movement of radioactive materials as defined in this International Standard, particularly across national borders, for subsequent illegal sale, use, storage or further transfer

3.6
inadvertent movement
any unintentional unauthorized receipt, possession, use or transfer of radioactive materials as defined in this International Standard

3.7
investigation level
quantity of radiation intensity (expressed as dose rate or equivalent) established by agreement, defined as the nominal radiation level at which an alarm is triggered and consequent investigation of individuals, vehicles or goods shall be established

NOTE This term is synonymous with (nominal) alarm level or (nominal) alarm-threshold setting and shall not be confused either with instrument-related alarm-threshold setting (see A.3) or with the detection limit.

3.8
monitoring
measurement of dose or contamination for reasons related to the assessment or control of exposure to radiation or radioactive substances, and the interpretation of the results

3.9
non-proliferation
broad term used in international agreements in relation to limiting the availability of nuclear material and thus reducing the capability for production of nuclear weapons

3.10
physical protection
measures for the protection of radioactive materials designed to prevent any unauthorized removal or sabotage

3.11
regulatory authority
authority or authorities designated or otherwise recognized by a government for regulatory purposes in connection with protection and safety

3.12
response
ratio of the indicated value to the conventional true value

NOTE "Value" may be ambient dose equivalent rate or another, monitor-specific signal, sufficiently proportional to radiation intensity.

3.13
safeguards
verification system within the framework of international non-proliferation policy, applied to the peaceful uses of nuclear energy and intended to maintain stringent control over nuclear material

3.14
special nuclear material SNM
highly enriched uranium and all forms of plutonium, see [5]

4 Monitoring instruments

4.1 Pocket-type instruments

4.1.1 General

Small gamma radiation detectors, which are roughly the size of a message pager, can be worn on a belt or carried in a pocket for hands-free operation and quietly alert the operator to the presence of radioactive materials. Because of their small size, these instruments are ideally suited for use by individual law enforcement officers and first responders to a radiation alarm, without requiring extensive training.

A pocket-type instrument is a small, lightweight, robust device which will alert the wearer to radiation levels above background from gamma and X radiation. A solid-state detector is most frequently used in the instrument to ensure the required sensitivity. It shall be maintenance free, of rugged construction, weather resistant and battery operated with adequate operation time of at least 12 h. There shall be an indication on battery condition. The alarm-threshold should be pre-adjusted before issuance to the officer, to account for the natural background radiation at the particular location. A pocket-type instrument should be able to produce three types of alarms, a visual (light), audible (tone), and vibrating (silent) alarm, when the radiation intensity exceeds the alarm-threshold. For covert operation, disabling of the audible alarm should be possible. The audible tone should change as a function of dose rate. A display should provide a simple (luminescent) indication, which is proportional to dose rate. This indication serves two purposes, radiation safety, i.e. to warn the officer of greater radiation levels, and as a search tool for locating radiation sources.

4.1.2 Operation

A pocket-type instrument should be worn on the body, pocket, belt or similar location. A self-testing feature should verify proper operation of the instrument before usage. False-alarms, i.e. alarms without radioactive materials present, will occur occasionally due to the fluctuations in background. When the alarm-threshold is set properly, e.g. about three times the natural background level, false-alarms should occur not more than once per day. Radiation triggering innocent alarms may be detected on an occasional basis. This is due to the fact that many objects contain small quantities of radioactive material such as natural thorium or uranium.

4.1.3 Calibration and routine checking

Like most radiation detectors, it is recommended that calibration be once a year by a qualified individual or maintenance facility.

A pocket-type instrument should be checked, on a daily basis if possible, for its continued ability to detect radiation. This may be done by placement of the instrument near a radiation check source and observing a repeatable radiation level.

4.1.4 Minimum requirements and test methods

4.1.4.1 Alarm-threshold

The system should provide adjustable threshold levels.

The alarm shall continue to operate in saturation conditions at high dose rates.

The instrument shall clearly indicate an alarm condition. If an alarm has been triggered, the indication shall continue for a specified minimum period which is not shorter than 5 s.

If the instrument provides an audible alarm, this shall be in excess of 85 dB at 30 cm.

4.1.4.2 Sensitivity for gamma radiation

Where the dose rate exceeds the investigation level of 1 µSv/h for a period of 2 s or more, an alarm shall be activated with a probability greater than 99 %. For background dose rates up to 0,2 µSv/h, the false-alarm rate shall be less on average than 2 in a 12 h period.

NOTE One method to verify these minimum requirements can be found in D.2.2.

4.1.4.3 Sensitivity for neutron radiation

If the instrument provides neutron detection capability, the detector shall alarm when exposed to a neutron flux emitted from a ^{252}Cf source of 0,01 µg (approximately 20 000 n/s) for a duration of 10 s, at 0,25 m distance, when the gamma radiation is shielded to less than 1 %. The probability of detecting this alarm condition shall be 50 %. The false-alarm rate shall be less on average than 6 in a 1 h period.

NOTE 1 The neutron dose rate corresponding to the irradiation conditions mentioned above would approximately be in the order of 3 µSv/h.

NOTE 2 One method to verify these minimum requirements can be found in D.3.1.

4.1.4.4 Uncertainty of dose rate indication

If the system provides a quantitative dose rate indication, this indication shall be in accordance with IEC 61526.

4.1.4.5 Environmental conditions

The instrument shall meet the minimum requirements in a temperature range of − 15 °C to + 45 °C and a relative humidity of at least 95 %, for non-condensing conditions.

NOTE One method to verify these minimum requirements can be found in D.4.1.

4.1.4.6 Mechanical and electromagnetic properties

See IEC 61526.

4.2 Hand-held instruments

4.2.1 General

Hand-held radiation monitors are small, battery-powered, instruments that measure the ambient background level and then calculate an alarm-threshold. They may contain microprocessors. Thus, these instruments can compensate for variations in the background level when turned on, or on command. These monitors continuously make short measurements of the radiation level and compare the results to the alarm-threshold. The hand-held monitors can effectively search pedestrians, packages, cargo, and motor vehicles. The hand-held monitor shall be maintenance free, of rugged construction, weather resistant and battery operated with an adequate operation time of at least 12 h. There shall be an indication of the battery condition.

The most significant difference between the hand-held and fixed installed monitors is the human factor that strongly influences the ability of a hand-held instrument to detect radioactive materials in the field. Training is therefore of vital importance. If the officer does not move the monitor in close proximity to any radioactive material that is present, it may not be detected.

The small hand-held instrument can be placed nearer to the radioactive material where the dose rate will be higher, thus yielding high sensitivity to radiation signature. To achieve that sensitivity, officers shall be trained in the proper technique to conduct effective searches, and the training shall be repeated periodically. These instruments should also have the capability to measure dose rate for radiation safety purposes.

4.2.2 Operation

Hand-held monitors are small radiation detection instruments that can be used as either the primary search device or as a second-stage search device for fixed stationary monitors. The monitor should be equipped with an audible alarm to enable the officer to perform the search without watching the device. For search applications, the instrument should have a handle that makes it easy to hold and it should weigh less than approximately 2 kg. The instrument should preferably use a solid state gamma detector. Neutron sensitivity would also be a desirable feature. The capability to distinguish between gamma and neutron alarms is preferable. These instruments shall make measurements on short time scales of approximately 1 s so that they can be used to scan quickly the surfaces of packages, pedestrians, vehicles and cargo. The instruments shall facilitate the localisation of radiation sources by either providing automatic reset of an alarm condition and/or a frequency dependence of the alarm indication on dose rate.

4.2.3 Calibration and routine testing

As for most radiation detectors, it is recommended that calibration be carried out once a year by a qualified individual or maintenance facility.

A hand-held instrument should be checked, on a daily basis if possible, for its continued ability to detect radiation. This may be done by placement of the instrument near a radiation check source and observing a repeatable radiation level.

4.2.4 Minimum requirements and test methods

4.2.4.1 Alarm-threshold

The system should provide adjustable threshold levels.

The alarm shall continue to operate in saturation conditions of high dose rates.

The instrument shall clearly indicate an alarm condition. If an alarm has been triggered and the actual dose rate falls below the alarm-threshold, the alarm indication shall be automatically and quickly reset.

If the instrument provides an audible alarm, this shall be in excess of 85 dB in 30 cm.

4.2.4.2 Sensitivity for gamma radiation

Where the dose rate exceeds the investigation level of 0,4 µSv/h for a period of 3 s or more, an alarm shall be activated with a probability greater than 90 %. For background dose rates up to 0,2 µSv/h, the false-alarm rate shall be less on average than 6 in a 1 h period.

NOTE 1 It is desirable that the instruments' response is faster for higher dose rates.

NOTE 2 One method to verify these minimum requirements can be found in D.2.4.

4.2.4.3 Sensitivity for neutron radiation

If the instrument provides neutron detection capability, the detector shall alarm when exposed to a neutron flux emitted from a ^{252}Cf source of 0,01 µg (approximately 20 000 n/s) for a duration of 10 s, at 0,25 m distance, when the gamma radiation is shielded to less than 1 %. The probability of detecting this alarm condition shall be 50 %. The false-alarm rate shall be less on average than 6 in a 1 h period.

NOTE 1 The neutron dose rate corresponding to the irradiation conditions mentioned above would approximately be in the order of 3 µSv/h.

NOTE 2 One method to verify these minimum requirements can be found in D.3.1.

4.2.4.4 Uncertainty of dose rate indication

If the system provides a dose rate indication, this indication shall be in accordance with IEC 60846.

4.2.4.5 Environmental conditions

The instrument shall meet the minimum requirements listed above in a temperature range of – 15 °C to + 45 °C and with a relative humidity of at least 95 %, for non-condensing conditions.

NOTE One method to verify these minimum requirements can be found in D.4.2.

4.2.4.6 Mechanical and electromagnetic properties

Shock-proofing of the instrument is desirable.

See IEC 60846.

4.3 Installed instruments

4.3.1 General

Installed radiation vehicle and pedestrian monitors are designed to detect the presence of radioactive material automatically by comparing the gamma and/or neutron intensity, while the monitor is occupied, to the continuously updated background radiation level which is measured (and updated) while the monitor is unoccupied. The use of suitable occupancy sensors is essential for achieving the required low false-alarm rate.

Preferably, gamma and neutron radiation levels should be measured and indicated separately. These monitors automatically search pedestrians or vehicles as they pass through the monitor. These monitors continuously measure the background radiation level and may adjust the alarm-threshold to maintain a constant false-alarm rate.

4.3.2 Operation

4.3.2.1 General

A fixed installed radiation portal monitor is only as effective as the “check point” where it is installed. The monitors shall be installed such that all the pedestrians, vehicles, and cargo traffic are forced to pass through the monitors. The effectiveness of fixed installed instruments is strongly dependent on its ability to measure the radiation intensity over the entire search area. It further requires that inspection officers promptly respond to alarms. These alarms may be remotely observed. Alarm indications should be in clear view of the officers manning the inspection point. Independent indication of gamma and neutron alarms should be provided.

NOTE The majority of detection will be the result of naturally occurring radioactive materials (e.g. fertilisers, specific varieties of pottery) or out-patients from nuclear medicine departments, see Annex E.

4.3.2.2 Pedestrian monitors

Pedestrian monitors may be installed as single- or dual-sided monitors. Barriers shall be installed to restrict the pedestrian traffic so that passage is within 1,0 m of the monitor. Where pedestrian traffic corridors are larger than 1 m, dual-sided monitors should be installed. The monitor should be placed away from heavy doors, which can cause excess false-alarms, since effective shielding by the doors may lead to increased fluctuations in the radiation background. The occupancy sensor shall be positioned so that it is only triggered when the instrument is occupied and not by individuals walking in the vicinity of the monitor. Because of the possibility of gamma shielding in luggage and packages, the monitors are most effective when they are used in combination with metal-detection systems which can be used to easily identify the presence of shielding material.

4.3.2.3 Vehicle monitors

Using fixed installed radiation monitors to search vehicles for radiation sources is complicated by the inherent shielding caused by the vehicle structure. While simple two-sided monitors are effective in detecting abnormal radiation levels in shipments of metals for recycling, they are much less effective in detecting illicitly trafficked radioactive materials when that material is purposely concealed.

Barriers, which do not obstruct the view of the monitor, should be installed to protect the monitor from being damaged by the vehicles. Since the sensitivity of the monitor is strongly dependent on monitoring time, the instrument should be placed where the speed of the vehicle is controlled and reduced.

For passenger vehicles, one-sided monitors are acceptable if the maximum passage width is limited to 3 m or less.

For large trucks and buses, two-sided monitors are required and the maximum distance between pillars should be less than 4,5 m (this is dependent on the maximum width of the vehicle to be scanned).

The speed of the vehicle shall be monitored, and where the vehicle’s speed exceeds that for effective monitoring, a specific alarm shall be given. The vehicle should not be allowed to stop while passing through the monitor. The occupancy sensor shall be positioned so that it is only triggered when the monitoring system is occupied and not by other traffic in the vicinity.

Detection assemblies should be mounted using methods that prevent or minimize the transfer of vibration transients caused by passing vehicles. Vibration transients that transfer to the detection assembly may cause degradation of the assembly or alarm activation.

4.3.3 Calibration and routine testing

The automatic portal monitor shall be calibrated and tested periodically.

Automatic portal monitors should be checked daily with small radioactive sources to verify that they can detect radiation intensity increases and corresponding alarms can be triggered.