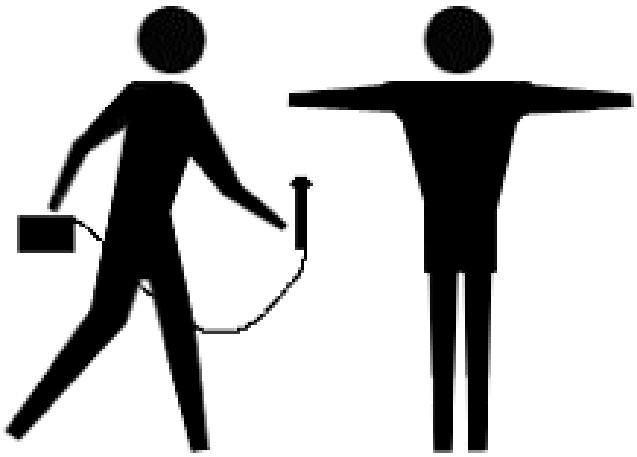
Contamination Monitoring Guidance For Portable Instruments Used For Radiological Emergency Response To Nuclear Power Plant Accidents



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CONTAMINATION MONITORING GUIDANCE FOR PORTABLE INSTRUMENTS USED FOR RADIOLOGICAL EMERGENCY RESPONSE TO NUCLEAR POWER PLANT ACCIDENTS

The Federal Emergency Management (FEMA) under the authority of Public Law 96-295 (1980) and in cooperation with members of the Federal Radiological Preparedness Coordinating Committee (FRPCC) in March 1995 promulgated the *Contamination Monitoring Standard for a Portal Monitor Used for Radiological Emergency Response*. That document, (commonly referred to as the "Portal Monitor Standard") provides FEMA's decontamination decision criteria for individuals when using portal monitors for radiological emergency response to commercial nuclear power plant accidents. In contrast, the guidance in this document is for the use of portable radiation instruments with hand-held detectors (commonly referred to as "portable instruments") for the monitoring of individuals, vehicles, equipment, and other possessions for radioactive contamination from nuclear power plant accidents. This guidance is supported by the document, *"Background Information on Contamination Monitoring Guidance for Portable Instruments Used for Radiological Emergency Response to Nuclear Power Plant Accidents"* dated October 3, 2002.

PURPOSE

The goal of this guidance is to provide emergency decontamination decision criteria for use with portable instruments such that the criteria are adequately protective of public health under emergency conditions, compatible with existing guidance for portal monitors, and supportive of contamination control. This involves two categories of guidance: (1) optimum procedures for detecting and measuring surface contamination at levels specified as decontamination or release decision criteria, and (2) a translation from decontamination (or release) criteria in units of microcuries (μCi) or $\mu Ci/cm^2$ into instrument readings (counts per minute) applicable to different portable instrument/detector combinations that are commonly used.

Individuals, vehicles and equipment that have been, or potentially have been, exposed to (1) an airborne plume containing radioactive material from an accident at a nuclear power plant or (2) contaminated surfaces resulting from material deposited from the passing plume may need to be monitored to determine whether decontamination is needed. Such monitoring may be accomplished for individuals using portal monitors or portable instruments.

This guidance is for the use of portable instruments during the emergency phase of a nuclear power plant accident to (1) provide reasonable assurance that the risk of skin cancer and other significant radiation effects to individuals exposed to contamination does not exceed guidelines established in 1992 by the Environmental Protection Agency (EPA) in the *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents* (EPA 400-R-92-001) and (2) to limit the spread of contamination to the extent practical for the instrument/detector combination being used. The guidance presented here is only for emergency control of exposure of the offsite public

to radioactive contamination from major accidents at nuclear power plants. It is intended for use during the emergency phase of an accident at reception centers for monitoring evacuees and their possessions and at emergency worker decontamination facilities to provide a basis for decisions on the need for decontamination, unconditional release, or referral for professional radiological evaluation. The guidance is limited in scope and does not apply to any of the following:

(1) Individuals or workers, as defined in 10 CFR 19.3, exposed under controlled conditions such as in a work-place environment,
(2) Contaminated equipment on-site at nuclear power facilities that is controlled by contamination limits in NRC Regulatory Guide 1.86,
(3) Accidental releases to the environment that have an isotopic mix that would not be expected from a nuclear power plant accident, or
(4) Professional evaluation of individuals for which decontamination has been unsuccessful in reducing contamination to levels less than the decontamination decision criteria recommended in this document.

The guidance provided here supersedes guidance on decontamination criteria for emergency response published by FEMA in the *Radiological Emergency Preparedness Exercise Manual* (FEMA REP-14 Sections D.18 and D.22) September, 1991, and the Contamination Screening Levels published by EPA in "EPA 400-R-92-001, Tables 7-6 and 7-7."

The guidance presented here is intended for use by State and local governments in their development of Radiological Emergency Response Plans for nuclear power facilities. Some State and local plans incorporate guidance that is more conservative (i.e., decision criteria have lower values) than those presented here. FEMA will approve plans with more conservative decontamination decision criteria if State monitoring capability justifies them (i.e., 20 percent of the plume EPZ population, including the estimated transient population, can be monitored within 12 hours using these criteria). For extenuating circumstances, FEMA will also consider approval of plans with higher decontamination decision criteria, not exceeding those in Table 6 of the Background Information Document.

Current State and local practices based on guidance in FEMA-REP-14 for monitoring individuals are generally adequate for protecting the public under emergency conditions. However, a notable exception is the guidance in FEMA-REP 2 indicating that 90 seconds is about the average time needed to monitor an individual using a portable instrument. Experiments conducted to provide a basis for the guidance presented here show that the time needed to monitor an individual varies with the type of instrument/detector being used and that none of the instruments tested could monitor an entire individual for spot contamination within the 90 second time frame when the contamination level is equivalent to the guidance level. The additional time requirements are a result of technical analyses associated with the Portal Monitor Standard (March 1995) which showed that small spots of relatively low levels of concentrated contamination would be more likely to produce health effects than would less concentrated widespread contamination. Earlier monitoring programs were not designed to locate these small spots of contamination.

BASIS

The Contamination Screening levels published in EPA 400-92-001 were based on minimum detectable levels for a specific type of contamination monitoring instrument (CD V-700 or equivalent). They did not take into account the EPA general guidelines in EPA 400-R-92-001 for using acceptable levels of risk of health effects as a basis for establishing contamination limits. FEMA, in REP-14, recognized the need for specific guidance values and proposed guidance of 300 counts per minute (cpm) above background as decision criterion for monitoring individuals using a CD V-700, but included a caveat that "this value is being reevaluated." This reevaluation has now been completed and the results are published in a Background Information Document as a companion to this guidance document.

The quantity of contamination on an individual that warrants decontamination was established by the Portal Monitor Standard on the basis of, (1) guidance on acceptable risk of health effects under emergency conditions provided in EPA 400-R-92-001, (2) estimates of exposure time for the skin, (3) the assumption that contamination will not be uniformly distributed, (i.e., it may consist of both a small spot[s] of concentrated contamination and widespread non uniformly distributed contamination), (4) concentrated spot contamination will not exist without the presence of widespread contamination, (5) that the quantity of widespread contamination on an individual is assumed to be at least 10 times the quantity of contamination on a small spot of skin, and (6) the controlling health effects will be "acute exudative radiodermatitis" from a small spot(s) of contamination and "skin cancer" from widespread contamination. It was concluded that the quantity of contamination on skin that warrants decontamination depends on whether the contamination is confined to one or more small spots or is widespread.

Conservative analyses supporting the Portal Monitor Standard showed that fixed contamination on a spot of skin having an area of 0.2 cm^2 or less should not exceed 0.1 µCi in order to avoid exceeding the dose threshold for acute exudative radiodermatitis. These analyses also showed that, in order to maintain an acceptable level of risk of skin cancer under emergency conditions, widespread fixed contamination on the total body should not exceed 74 µCi, regardless of its distribution. For uniformly distributed contamination on an adult, 74 µCi corresponds to 0.004 $\mu Ci/cm^2$. Additional information on the health risks associated with skin contamination can be found in Section II of the Background Information Document.

INSTRUMENT CALIBRATION

Portable instruments used for evaluation of contamination levels in accordance with this guidance will detect and measure primarily beta radiation, but also some gamma radiation. CD V-700 instruments with the side window detector and those with the pancake detector as well as the CD V-718 instrument with the end window detector were all calibrated using only gamma radiation from a sealed Cs/Ba-137 source. Other more modern instruments with pancake detectors were calibrated by the manufacturer to respond in the range of 3000 to 4000 counts per minute (cpm) per mR/h of gamma radiation. The criteria presented here apply only to instrument/detector combinations that have been calibrated in this same manner (i.e., either using Cs/Ba gamma radiation or in accordance with manufacturer's recommendations). CD V-700 instruments should be calibrated annually and other instruments should be calibrated at a frequency recommended by the manufacturer. Portable instruments that are outside the

categories listed herein, should be tested to determine their response to a 0.1 μCi Cs/Ba beta source at 1 inch from the detector. For a list of the portable instrument/detector combinations that were tested to support the guidance in this document, see Table 2 of the companion Background Information Document.

MONITORING PROCESS

Monitoring of individuals for detection and measurement of contamination with portable radiation instruments that incorporate a movable beta-gamma detector is a four-step process as follows:

1. A speaker or earphone(s) attached to the instrument is used to audibly announce the presence of contamination. With the beta window open, the detector is passed over a potentially contaminated surface at a specified,
   - probe speed,
   - distance between the probe and the contaminated surface, and
   - distance between passes of the probe (path-width).
2. If contamination is detected, the earphone(s) or speaker is used to find either, the location of the most active spot(s) of contamination, or the location of the highest concentration(s) of widespread contamination.
3. A meter reading is then taken with the detector in a fixed position at the location of the highest audible response and at one inch from the monitored surface. Visual estimation of one inch is satisfactory because small errors in this distance will be compensated by conservatism in the decontamination threshold criteria. Measurements at less than one inch will add more conservatism to decisions on the need for decontamination.
4. The meter reading is compared to the decontamination decision criteria.

Step 1 above (detection) would likely take place at a monitoring center established for this purpose. Steps 2, 3 and 4, could take place right after detection, in which case only those with contamination equal to or greater than the decontamination criteria would be sent to decontamination while others found to be not contaminated in excess of the decontamination criteria would be released. If the criteria for loose-plus-fixed contamination are used, the released individuals should be advised to bathe and change clothes within 24 hours. If decontamination facilities are adequate, instead of measuring the contamination level, those with detectable contamination could be sent to decontamination prior to steps 2, 3, and 4. After decontamination they would be monitored again to determine whether the decontamination was successful. Additional variations on this process are discussed after Table 1.

DETECTION PARAMETERS FOR INDIVIDUALS

Empirical data have been developed regarding optimum combinations of probe speed, probe height, and path-width for audible detection of spot contamination at levels corresponding to the decontamination decision criteria for individuals for several typically-used instrument/detector combinations. The resulting data for these parameter values are presented in Table 1. Although the parameter values were derived for spot contamination, they are more than adequate to detect widespread contamination at levels of concern for risk of skin cancer. Derived values in Table 1

for probe speed are expressed as a single value. However, detection is not highly sensitive to probe speed, and errors in probe speed of ±50 percent would not significantly affect the accuracy of detection. The data for path-width have been reduced from the measured maximum values by factors of 30 to 50 percent to accommodate potential errors (e.g., beta shielding from use of probe covers and errors in maintaining the specified probe speed and probe height).

It would be reasonable to expect background radiation levels to rise in an emergency monitoring center because of contamination on equipment, walkways, clothing, and waste. Therefore, the derived parameters for detection of contamination were determined in the presence of background gamma radiation levels of 0.02 mR/h and 0.1 mR/h. As indicated in the footnotes to Table 1, some of the instruments did not perform well for audible detection of contamination in the presence of the 0.1 mR/h background. However, all of the instruments that used a pancake detector and that had a good audio system performed well for detection in the presence of the higher (0.1 mR/h) background.

TABLE 1:

Recommended Parameter Values For Detecting Contamination on Individuals[a]

Instrument/ Detector Combination	Parameter Values for Detecting Spot or Widespread Contamination on Individuals			Calculated Time Needed to Monitor an Adult (minutes)
	Probe Speed (inches/second)	Height of Probe (inches)	Path Width (inches)	
CD V-700 with side window detector[b]	4	0.25 to 0.5	0.6	19
CD V-718 with end window detector	3	0.5 to 1	1	12
All tested instruments with pancake detectors, except the Victoreen 190	6	1 to 3	2	3.9
Victoreen 190 with pancake detector[b]	6	1 to 4	3	2.6

a. These values are based on the ability to detect 0.1 µCi of contamination on a small spot of skin in background gamma radiation levels up to 0.1 mR/h, except as noted. Refer to Table 4 of the Background Information Document for more detailed information.

b. Audible detection is not possible in a background gamma radiation level of 0.1 mR/h. Values are for use in background levels of 0.02 mR/h or lower.

Under some circumstances it may be appropriate to adjust emergency response plans and procedures for monitoring evacuees to assure the best protection of the public. This may require

adjustments that take into account equipment shortcomings and time constraints for completing the monitoring more rapidly. FEMA will approve justified changes to monitoring procedures to reduce monitoring times.

Examples of alternative approaches that might be used to permit faster monitoring are:

1. Initially scan areas on evacuees where contamination would most likely be found (e.g., head, hands, elbows, thighs in areas where the hands would naturally contact, knees and shoe soles). This monitoring could be completed in about 1/5 the times shown in Table 1. Those for which no contamination was found would be released and advised to bathe and change clothes at their first opportunity within the next 24 hours. Those found to be contaminated would be referred to decontamination followed by a complete monitoring of areas that were not protected by clothing. Removed clothing would be monitored only for widespread contamination which would require only a few quick passes.

2 Identify geographical areas where contaminated evacuees may have been exposed to contamination and send individuals from those areas directly to decontamination (e.g., showers) without prior monitoring, but with follow up monitoring after decontamination.

3. Separate the evacuees into two groups, (1) those who have not bathed, changed clothes or been decontaminated since evacuating, and (2) those who have bathed, changed clothes or been decontaminated. Group 1 could be monitored using the faster detection parameters derived for loose-plus-fixed contamination (see Table 4 of the companion Background Information Document). Group 2 should be monitored using the detection parameters derived for fixed contamination as shown in Table 1 above.

4. Some of the above suggestions might be combined to further increase monitoring speed.

MEASUREMENT CRITERIA FOR INDIVIDUALS

Contamination monitoring instruments do not respond in units associated with the risk-related decontamination criteria (μCi or μCi/cm^2). Therefore, to evaluate whether the criterion is exceeded by contamination found at a particular location, one must compare the instrument's response (cpm) to a predetermined response of that instrument/detector combination to contamination at the level of the decontamination decision criterion. This predetermined response will be a function of the type of instrument/detector being used and the distance of the detector from the contaminated surface.

Instead of recommending different criteria for each type of instrument/detector combination as derived based on risk of health effects, this guidance recommends a single value equivalent to the criteria derived for the least sensitive instrument. The response of four commonly-used instrument/detector combinations has been empirically determined at one inch as measured from the detector housing to the contaminated surface, and the resulting data are presented in Table 6 of the Background Information Document. The recommended decision criterion for individuals

(300 cpm above background) for all the tested instrument/detector combinations that read out in cpm is the same as the empirically derived value in Table 6 of the Background Information Document for the least sensitive instrument/detector combination (the CD V-700 with a standard detector). When this criterion is used with the more sensitive instrument/detector combinations, additional protection from skin cancer and from contamination spread will be provided. The additional protection factors are shown in column 4 of Table 2.

TABLE 2

Recommended Decontamination Decision Criteria for Individuals When Using Selected Portable Instrument/Detector Combinations

Instrument Type	Detector Type	Recommended Decontamination Decision Criteria[a]	Factor of Safety Applied to Derived Criteria[b]
CD V-700	Standard GM Side Window	300 cpm	1
CD V-700	GM pancake	300 cpm	3.3
CD V-718	Standard GM End Window	1.0 mR/h[c]	1.3
Count Rate Instruments that calibrate at 3,000 to 4,000 cpm per mR/h	GM Pancake	300 cpm	33

a. These are open-beta-window readings above background.

b. These factors, when multiplied times the Decision Criteria in column 3, produce the count rate for fixed contamination that was derived on the basis of acceptable level of risk of health effects under emergency conditions. Use of the Decision Criteria in column 3 reduces the risk of skin cancer and contamination spread by the factors in column 4.

c. This instrument does not read out in cpm. With the beta window open, this is only an instrument response; not a true reading of mR/h. This instrument should not be confused with the CD V-718-A which accommodates a pancake detector and reads out in cpm.

To use the guidance in Table 2, one should first locate the peak concentration of contamination using the methods described in the previous Section. Then a reading should be taken with the beta-sensitive area of the detector located at approximately one inch from the peak concentration. The decontamination decision criteria in terms of instrument response are the same for spot and widespread contamination. The empirical data supporting the decision criteria are presented in Tables 5 of the Background Information Document. These data were collected with the detector covered by two layers of plastic vegetable wrap (e.g., *Saran Wrap* or *Glad Wrap*) which had a density thickness of about 1.1 mg/cm^2. The data in Table 2 are derived from summary data in Table 6 of the Background Information Document.

"Counts per minute (cpm)" is the proper unit for instrument readings when measuring beta-gamma emitting surface contamination. However, some instrument types that have capability to detect both beta and gamma radiation have a read-out only in mR/h, (the unit for exposure rate from x-ray or gamma radiation). This is the case for an older version of the CD V-718 listed in Table 2. With the beta window open, it detects both beta and gamma radiation, but the reading in mR/h is technically inappropriate. The use of instruments that do not have a "cpm" read-out is discouraged. However, such instruments can be used to evaluate contamination levels if they have been tested to determine their response when the detector, with the beta window open, is at one inch from a surface that is contaminated to the level of the decontamination decision criteria.

MONITORING OF VEHICLES, EQUIPMENT AND OTHER POSSESSIONS

Contrary to the situation for contamination on individuals, the risk of health effects from contamination on vehicles, equipment, and other possessions is primarily from loose contamination (i.e., that which can be removed by decontamination). However, contamination remaining after decontamination (fixed contamination) is also of concern.

Loose-Plus-Fixed Contamination:

The decontamination decision criteria in Table 2 for individuals and the associated measurement procedures (i.e., measurements at one inch from the contaminated surface) are also recommended for monitoring for loose-plus-fixed contamination on vehicles, equipment, and other possessions.

As discussed following Table 3, the detection parameters listed in Table 4 are appropriate for both fixed contamination and loose-plus-fixed contamination.

Fixed Contamination:

Contamination on vehicles, equipment and other possessions that is not removed by decontamination (fixed contamination) is not a problem with regard to contamination spread or contamination transfer to individuals. However, it has the potential for long term direct exposure of individuals to beta and gamma radiation. The greatest risk of health effects from fixed contamination on vehicles, equipment, and other possessions is skin cancer from beta radiation in situations where skin may be in contact with a contaminated surface for extended periods of time (e.g., auto seats and steering wheel. Section VI of the Background Information Document concludes that during the emergency phase of a nuclear power plant accident, an initial concentration of 0.0085 $\mu Ci/cm^2$ of fixed contamination on vehicle seats represents a threshold for detection and measurement. Concentrations twice as high, or more, could be permitted on other surfaces (e.g., exterior of vehicles) where skin would not be exposed at close range for extended periods.

Based on empirical data and calculations presented in Section VI of the Background Information Document, Table 3 provides decision criteria for fixed contamination on vehicles, equipment, and other possessions that have been decontaminated. These criteria are recommended for use in developing radiological emergency response plans for use by monitoring teams at reception centers and emergency worker decontamination centers during the emergency phase of an accident.

TABLE 3

Recommended Decision Criteria For Releasing Vehicles, Equipment, And Other Possessions

Instrument Type	Detector Type	Decision Criteria for Release[a] Beta-Plus-Gamma	
		Loose-Plus-Fixed	Fixed
CD V-700	Standard Side Window	300 cpm	1,000 cpm[b]
CD V-700	Pancake	300 cpm	5,400 cpm
CD V-718[c]	Standard End Window	1.0 mR/h[d]	2.3 mR/h[d]
Modern[e]	Pancake	300 cpm	36,000 cpm

a. These criteria are based on limiting the concentration of widespread loose-plus-fixed contamination to levels consistent with the levels established for decontamination of individuals and to limit fixed contamination to less than 0.0085 µCi/cm^2. Values are "above background" and as read at one inch from the contaminated surface.

b. If a uniform criteria for all instrument/detector combination is desired for fixed contamination, 1000 cpm would be appropriate. The value of 2.3 mR/h for the CD V-718 would not change.

c. This instrument does not have a read-out in cpm.

d. With the beta shield open, this is not an actual exposure rate in mR/h. It is only a derived meter indication.

e. "Modern" refers to instruments more modern than the CD V-700 which was last manufactured in 1962.

FEMA will approve plans with numerically lower criteria values where justified. Contamination spread or transfer to individuals is not a problem for fixed contamination, so there is no justification for lower values on this basis. However, for simplifying the criteria where different instrument/detector combinations may be used, 1,000 cpm (same as 2.3 mR/h for the CD V-718) may be selected as a uniform criterion.

Since spot contamination is not an issue for vehicles, equipment, and other possessions, the detection parameters listed in Table 1 do not apply. Empirical data reported in Section VI.E, Table 10 of the Background Information Document show parameters that are appropriate for detecting widespread contamination in the presence of 0.1 mR/h background gamma radiation. These data are repeated in Table 4 below along with the corresponding decision criteria for vehicles, equipment and other possessions with either loose-plus-fixed or fixed contamination. The decision criteria are shown as a function of type of instrument/detector being used and for both loose and fixed contamination as explained in the footnotes to Table 4. The parameter data show that probe speed can be relatively fast. Therefore, care should be taken when monitoring small objects or areas to assure that the probe speed will permit adequate time for the instrument to audibly respond (usually about 1 to 2 seconds) while the probe is being passed over the potentially contaminated object or area. Appropriate path width is a judgment call depending on the size of the surface being monitored and whether it represents the portion of the item most likely to be contaminated.

Instead of monitoring an entire large object, judgment should be used to determine the most

likely areas to be contaminated and then concentrate on those areas. Using automobiles as an example, the tires, bumpers, inside the fenders, door handles, air filter, steering wheel, floor, and seats would be the most likely parts to be contaminated. If the most likely parts or areas are found to be not contaminated in excess of the criteria, the item can be released.

TABLE 4

Recommended Detection Parameters for Widespread Contamination on Vehicles, Equipment and Other Possessions.

Instrument/ Detector Type	Decision Criteria	Detection Parameters	
		Maximum Probe Height (inches)	Maximum Probe Speed (inches/second)
CD V-700 with side Window detector	300 cpm[a]	1	6
	1,000 cpm[b]	2	12
CD V-700 with pancake detector	300 cpm[a]	1	12
	5400 cpm[c]	4	24
CD V-718 with end window detector[d]	1.0 mR/h[e]	1	6
	2.3 mR/h[f]	3	12
Modern instruments w/pancake detector	300 cpm[a]	10	24
	36,000 cpm[g]	10	24

a. This is the release criterion at one inch recommended for widespread loose-plus-fixed contamination for all instrument/detector combinations that read out in cpm.

b. This is the release criterion at one inch recommended for the CD V-700 with an side window detector for widespread fixed contamination.

c. This is the reading at one inch from the derived decision criterion concentration of 0.0085 µCi/cm^2 for fixed contamination when using the CD V-700 with a pancake detector.

d. This instrument reads out only in mR/h.

e. This is the release criterion at one inch recommended for widespread loose-plus-fixed contamination for this CD V-718 instrument/detector combination.

f. This is the reading at one inch from the derived decision criterion concentration of 0.0085 µCi/cm^2 for fixed contamination for the CD V-718 with the end window detector.

g. This is the reading at one inch from the derived decision criterion concentration of 0.0085 µCi/cm^2 for fixed contamination when using modern instruments with pancake detectors.

CONCLUSIONS

1. An individual who is monitored for contamination using a calibrated portable instrument

as discussed, and is found to not have contamination in excess of the criteria will have no significant risk of detrimental health effects from radiation exposure from contamination on the skin and clothing. During the early phase of the emergency, this level of detection will be adequate for the screening of evacuees and emergency workers for radioactive contamination. During the post emergency phase of an accident, these criteria may be used until technical evaluations of the actual mix of radionuclides are completed and revised decision criteria are developed based on those evaluations.

2. Decontamination decisions for individuals based on these criteria for portable radiation instruments will be as protective from the controlling deterministic health effect (acute exudative radiodermatitis) as decisions based on criteria for portal monitors as set forth in the *"Contamination Monitoring Standard for a Portal Monitor Used for Radiological Emergency Response."*

3. Using the recommended decision criteria for monitoring individuals, vehicles, equipment, and other possessions, will provide protection from health effects well within the EPA guidelines for emergency response.

4. The best combination of instruments for monitoring speed, protection of evacuees from health effects, and for controlling the spread of contamination is initial screening using portal monitors that comply with the Portal Monitor Standard and, if found to be contaminated, followed after decontamination by modern portable instruments with pancake detectors.