Potential Impacts of ICRP 60 and 61 on the Transportation Regulations*

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INTRODUCTION

The International Commission on Radiation Protection (ICRP) has been providing recommendations for limitations on radiation exposure for decades. The ICRP recommendations address ionizing radiation and are concerned with protecting humans from its effects. These recommendations assist regulatory and advisory agencies in establishing and promulgating national regulations and practices in radiation protection. Most countries have incorporated at least some aspect of the recommendations in their regulations since about 1956 when the first basic protection standard was published in ICRP 2. Since that time ICRP has issued two major revisions to the recommendations. ICRP 26 was published in 1977 and ICRP 60 was published in 1991. These last two publications have companion works, ICRP 30 and ICRP 61, that contain Annual Limits of Intake (ALI) for radiation workers.

In addition to national regulations, international regulations also reference or are based on the ICRP recommendations. The International Atomic Energy Agency (IAEA), which publishes basic requirements for protection against exposure to ionizing radiation and radioactive materials in Safety Series (SS) No. 9 (IAEA 1982), cites the ICRP recommendations as the basis for its standards. The requirements of SS No. 9 provide the framework for all other IAEA endeavors related to radiation protection.

IAEA's most important publication for the transport community is SS No. 6, *Regulations for the Safe Transport of Radioactive Materials* (IAEA 1990a). SS No. 6 embodies the basic radiation protection requirements of SS No. 9 in paragraphs 201–206. These paragraphs contain the basic transport-related requirements for controlling exposures to workers, the general public, and the environment through radiation protection programs [e.g., as low as reasonably achievable (ALARA)], and the development of separation and segregation distances. Because SS No. 6 must be consistent with SS No. 9, any changes to the ICRP recommendations have a trickle down effect into SS No. 6.

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SAFETY SERIES NO. 6 RADIATION PROTECTION MEASURES

To ensure a high level of safety of people, property, and the environment against radiation exposure, SS No. 6 provides standards for limiting exposure to transport workers and the general public. The basic standards on which SS No. 6 is based are found in SS No. 9.

In addition to the basic radiation protection program dictated by paragraphs 201–206, SS No. 6 relies heavily on dose rate, material, and contamination limits to control exposures. Among these limitations are:

- restrictions on the external dose rate levels for packages and conveyances;
- constraints on the number of packages that may be placed together or in proximity to persons and film (segregation and separation);
- limits on the maximum quantity of radioactive material allowed in a package that has not been certified for response to hypothetical accident conditions; and
- controls on allowable contamination.

Each of the radiation protection-oriented requirements of SS No. 6 is based, in part, on the occupational dose limits of SS No. 9 and hence, ICRP. For example, the external dose rate limit on the surfaces of packages of 2 mSv/h is based, in part, on a model that assumes transport workers handling packages will have limited direct contact with the package. This limited duration exposure, when combined with the package dose-rate limits, predicts that workers will not receive a dose in excess of the SS No. 9 limit. Studies indicate that typical transport activities cause doses less than 20 mSv, which is less than the 50 mSv limit in the current regulations (Shuler 1989). Similarly, limits on allowable fixed contamination, nonfixed contamination, and activity and specific activity limits in materials allowed in nonaccident resistant packages are all based on models that are used to determine the numerical values for the limits.

Limitations on package contents (total activity) of nonaccident resistant packages are determined by specified quantities called A-values. A-values were first introduced in the 1973 edition of SS No. 6 and are radionuclide-specific values to limit the potential hazard presented by these packages. Because of the pragmatic nature in which the A-values had been developed for the 1973 edition, Macdonald and Goldfinch of the United Kingdom under a research agreement with IAEA, reexamined and refined the dosimetric models used in the calculations of these values (IAEA 1990b). The resulting model for Type A package contents limits, known as the Q-system, introduced in the 1985 edition of SS No. 6 redefined A-values.

The Q-system incorporates the recommendations of ICRP 26 and is based primarily on the following two fundamental assumptions, that the effective or committed effective dose equivalent to a person exposed in the vicinity of a transport package following an accident should not exceed the annual dose limit for radiation workers (50 mSv), and that the dose received by individual organs should not exceed 0.50 Sv or, for the special case of the eye, 0.15 Sv. These dose limitations are found in ICRP 26, which as discussed earlier, formed the basis for SS No. 9.

The Q-system considers six exposure pathways, including direct photon and beta exposure, inhalation and ingestion of radioactive materials, skin exposure, and exposure from cloud submersion, using ICRP dosimetric models. In three of the pathways, inhalation, ingestion, and submersion, the Q-system directly uses the ALI and the Derived Air Concentration, which are tabulated in ICRP 30. The ICRP 30 values are derived from the fundamental principles of ICRP 26 for dose limits. The remaining pathways use the basic assumptions of ICRP 26 and derive A-values from those principals. Consequently, changes to the ALIs as published in ICRP 61 potentially have a profound effect on the A-values. The IAEA convened a Technical Committee meeting (TCM-800) to examine this and related questions.

A-values are used throughout SS No. 6 for establishing radiation protection-related limits. Primarily, the A-values, or fractions of them, are used to limit the quantity of material (or the material characteristics) that may be placed in the various types of nonaccident resistant packages (excepted, industrial, and Type A). Breaches in the integrity of the these packages is unlikely to cause a dose, which may be experienced by a worker during a response to an incident, to exceed an acceptable level (as specified in SS No.9).

SS No. 9 and ICRP play important roles in transportation-related dose limitation, especially as they are used to derive restraints on direct radiation levels or limits on package contents. The A-values in particular are used widely in SS No. 6. Consequently, changes in SS No. 9 and ICRP have potentially serious effects on the transport regulations.

CHANGES IN THE ICRP RECOMMENDATIONS AND THEIR ADOPTION INTO SAFETY SERIES NO. 6

Several significant changes were introduced in ICRP 60 that could impact the requirements in SS No. 9, and subsequently, all other IAEA regulations that build on SS No. 9. Those changes that may have the most significant direct impacts include (Rawl 1992):

- a reduction in the dose limits for occupational exposure from 50 to 20 mSv/year averaged over defined periods of 5 years with no single year to exceed 50 mSv;
- moving from a system of dose limitation to one of radiological protection that includes not only normal exposures, but also situations where probability of exposure exists;
- the introduction of dose and risk constraints and their recommendation as regulatory requirements; and
- new radiation weighting factors for neutrons that are approximately doubled for neutrons with energy of 2 MeV and less.

The potential impacts that these changes may have on the transport regulations depends on how they are incorporated into the regulations. The process of considering and adopting the changes has begun as part of IAEA's effort to revise SS No. 6 by 1996. TCM-800 met in June 1992 to consider how these changes should be addressed during the revision of the transport regulations. Several significant recommendations were made that will be forwarded to the Revision Panels and other groups that will formulate the 1996 edition of the transport regulations.

Reductions in the Dose Limits

The reduction in the dose limits for occupational exposure has the most significant potential impact on the transport regulations. The previous occupational dose limit (50 mSv/year) was used as a basis for calculating the A-values. The Q-system applies a set of assumptions, such as a person is unlikely to unwittingly remain in the vicinity of a damaged package for more than 0.5 h at a distance of 1 m, to calculate the activity of each radionuclide that is allowed in a Type A package (IAEA 1990b). Other bases, such as a dose limit of 0.5 Sv for individual organs, including the skin, and 0.15 Sv for the lens of the eye are used to provide other appropriate limits.

A direct reduction of the annual dose limit from 50 to 20 mSv/year was used by ICRP in calculating new ALI for radionuclides (ICRP 1990). Because of other changes in the ICRP methodologies, such as revisions to the dosimetric models, the ALI value reductions are not linear, and in the case of some alpha-emitting radionuclides, the values actually increase. However, the reduced dose limits generally produce allowable ALI values that are two to three times lower. TCM-800 considered the need to incorporate the lower dose limit and concluded that such a move was not needed. The agreement to retain a 50 mSv basis for the Q-system was based on the recognition that the dose limit was accident- and potential exposure-based and was independent of the ICRP recommendations. The 50 mSv limit was justified on the basis that:

- it is well below any nonstochastic limit recommended by the ICRP;
- combined with the low probability of exposure, it is acceptable within the criteria for potential exposures;
- it lies toward the lower end of the ranges of dose limits recommended for radiation accident countermeasures; and
- experience shows that exposures received in practice are well below the 50 mSv value.

A reduction in the dose limits for occupational and public exposures could also affect the allowable dose rate at the surfaces of packages. Exposures resulting from normal transportation are not modeled by the Q-system but are based on mode-specific scenarios that assume certain geometries, distances, and durations at the regulatory dose rate limits. TCM-800 considered the need to reduce package surface and transport index limits and concluded that, when considered in conjunction with optimization programs, no overall reductions in the package and conveyance dose rate limits were needed.

While the actual exposures to the public that occur as a result of transport are generally very low, they are controlled by separation requirements that are based on a limit of 1 mSv/year. If the 1 mSv limit for public exposure is applied within the framework of the ICRP constraint that no single activity exceed a small fraction of that limit, the separation tables used to control normal exposures need to be reconsidered. This will likely result in a reduction of the allowable number of packages on a conveyance or a commensurate increase in the required separation distances. TCM-800 recommended that IAEA communicate the need for such a reevaluation and request relevant information from Member States and affected international transport agencies, such as the International Civil Aviation Organization.

System of Radiological Protection
The ICRP recommendations have been expanded to a system of radiation protection that includes limits on risks to individuals as well as limits on expected exposures from normal operations. While no specific values for risk limits are recommended, the selection of extremely low values could have an impact on transportation. TCM-800 considered the issue of risk limits but did not develop a consensus on what appropriate risk values should be nor how compliance with such values should be demonstrated. Additional work in developing the ICRP recommendations into useable risk limit values (such as through SS No. 9) is needed to clarify what is necessary. The transport community then will be faced with evaluating its compliance with those recommendations.

Dose and Risk Constraints
The ICRP recommendations include the principle that radiation protection should optimized (kept ALARA) with relation to any particular source within a practice. This procedure is further constrained by restrictions on the doses to individuals (dose constraints) and the risks to individuals in the case of potential exposures (risk constraints) to limit the inequity that might occur. Transport is a practice to which such constraints might apply.

TCM-800 recognized that dose constraints might be appropriate for transport but could not develop specific values to be applied. The technical committee did, however, develop specific text for SS No. 6 requiring specific actions for optimization programs applicable to all transport activities (carriers and shippers). New text for SS No. 6, paragraphs 201–206, was prepared that would require that a structured and systematic optimization program be developed, adopted, documented, and made available to the Competent Authority (upon request) whenever exposures may occur. Proposed paragraphs 201–206 will provide the radiation protection basis for SS No. 6 in the future and warrant careful consideration by all parties involved in transport.

Neutron Weighting Factors
ICRP has recommended radiation weighting factors that replace previously used quality factors for weighting the absorbed dose to account for the quality of the radiation of interest. In most instances, such as for gamma radiation, this produces no significant change. Neutrons with energies of less than 2 MeV, however, have radiation weighting factors that are approximately two times higher than their previous quality factors. The higher radiation weighting factors must be taken into account when determining the dose rates from packages that contain neutron producing contents. TCM-800 acknowledged this change and observed that SS No. 6 must strictly follow SS No. 9 in this regard.

Changes in the A-values

The recommendations of ICRP contained in Publication 60 incorporate newer information on the health aspects of radiation exposures derived from the studies of the Japanese A-bomb survivors in estimating the probability of a fatal cancer. ALI derived from the recommendations of ICRP 26 were contained in ICRP 30 and used in the derivation of the A-values. ICRP 61 contains ALI based on the primary radiation protection recommendations of ICRP 60 and the dosimetric data of ICRP 30.

Several aspects of the newer guidance have a direct bearing on the numerical values of the dosimetric quantities that enter into the Q system. The primary radiation protection quantity, effective dose, takes into account the relative contribution of specific tissues to the total risk when the body is uniformly irradiated. The effective dose E is defined as

$$\begin{aligned} E &= \sum_T w_T H_T \\ &= \sum_T w_T \sum_R w_R D_{T,R} \end{aligned} \tag{1}$$

where $D_{T,R}$ is the absorbed dose in tissue T from radiation R, w_R is the radiation weighting factor for radiation R, and w_T is the tissue weighting factor reflecting the relative contribution of tissue T to the total risk. H_T is the equivalent dose in tissue T. The values for w_R largely correspond to the average quality factor values used earlier with internal emitters. The values for the tissue weighting factors used in the 1977 and 1990 Recommendations of the ICRP are shown in Table 1 (ICRP 1977, 1990)

The effective dose quantity as defined in the 1990 Recommendations of the ICRP is given in Eq. 1 with the tissue weighting factors listed in Table 1. As evident from Table 1, the 1990 Recommendations assign specific weights to a number of tissues that in the 1977 Recommendations were only considered as part of the "remainder" tissue group. This was possible largely a result of the increased medical follow-up period in the epidemiological studies that permitted risk estimates to be developed for these cancers. In addition, the manner in which the remainder group of tissues is handled in the calculations has been further specified. The skin is now included as an organ in the overall summation of doses instead of being treated as an organ with a separate dose limit.

Tissue or Organ	Tissue Weighting Factor, w_T	
	ICRP 26	ICRP 60
Gonads	0.25	0.20
Red Marrow	0.12	0.12
Colon		0.12
Lung	0.12	0.12
Stomach		0.12
Urinary Bladder		0.05
Breast	0.15	0.05
Liver		0.05
Esophagus		0.05
Thyroid	0.03	0.05
Skin		0.01
Bone Surface	0.03	0.01
Remainder	0.30[a]	0.05[b,c]

Table 1. Tissue Weighting Factors

[a] A value of 0.05 is applicable to each of the five remaining organs or tissues receiving the highest dose.

[b] The remainder is composed of the following tissues and organs: adrenals, brain, small intestine, upper large intestine, kidney, muscle, pancreas, spleen, thymus, and uterus. The weighting factor is to be applied to the average dose in the remainder group.

[c] If a member of the remainder receives an equivalent dose in excess of the highest dose in any of the 12 organs for which weighting factors are specified, a weighting factor of 0.025 should be applied to that organ and a weighting factor of 0.025 applied to the average dose in the rest of the remainder.

The committed effective dose based on the 1990 tissue weighting factors is compared with the committed effective dose equivalent based on the 1977 weighting factors in Table 2. The data illustrate the robust nature of the effective dose in that changes in tissue weighting factors largely have a minor numerical effect on the effective dose per unit intake. For nuclides that fairly uniformly irradiate the tissue of the body; e.g., H-3 and Cs-137, the changes in weighting factors do not alter the numerical values. For the radioiodines, the effective dose is determined by the irradiation of a single target, the thyroid. Because the new weighting factor for the thyroid is somewhat higher (0.05) than the earlier value (0.03), the effective dose per unit intake for I-131 in Table 2 is about 1.7 times greater for the new weighting factors. Similarly, for bone-seeking radionuclides the effective dose per unit intake has decreased due to the lower weighting factor applied to bone surface (0.01 vs 0.03) — see Ra-226 and Pu-239.

Nuclide	Inhalation (Sv/Bq)		Ingestion (Sv/Bq)	
	ICRP-26	ICRP-60	ICRP-26	ICRP-60
H-3	1.73E-11	1.73E-11	1.73E-11	1.73E-11
Fe-55	7.26E-10	6.34E-10	1.64E-10	1.52E-10
Se-75	1.95E-09	1.57E-09	2.60E-09	2.13E-09
Sr-90	6.47E-08	5.04E-08	3.85E-08	3.10E-08
Tc-99m	8.80E-12	1.10E-11	1.68E-11	2.00E-11
I-131	8.89E-09	1.47E-08	1.44E-08	2.39E-08
Cs-137	8.63E-09	8.56E-09	1.35E-08	1.35E-08
Ra-226	2.32E-06	2.17E-06	3.58E-07	2.25E-07
Pu-239	1.16E-04	6.87E-05	9.56E-07	5.62E-07

Table 2. Committed Effective Dose Coefficients

Table 3 compares the A- values for a few radionuclides under the Q-system with those derived using the 1990 definition of effective dose. Both systems use the same dose limitation, an effective dose of 50 mSv. However, the Q-system considered the dose to the skin as a separate constraint, limited to 0.5 Sv, while ICRP 60 includes the skin as a weighted organ. There is some impact to the A_1 values (roughly equal to rounding effects) due to including skin dose in the effective dose. The changes with respect to A_2 are largely associated with changes in weighting factors for bone surfaces and the thyroid. These changes are enhanced since the Q-system conservatively equated ALI with an effective dose of 50 mSv even when ALI is based on nonstochastic considerations.

Nuclide	Current		Revised		Current/revised	
	A_1	A_2	A_1	A_2	A_1	A_2
Ac-225	0.6	0.01	0.6	0.02	1	0.50
Am-241	2.0	0.0002	2.0	0.0008	1	0.25
Au-198	3.0	0.5	2.0	0.5	1.6	1.0
C-14	1.0	0.5	0.8	0.5	1.25	1.0
Cf-252	0.1	0.001	0.09	0.001	1.0	1.0
Co-58	1.0	1.0	1.0	1.0	1.0	1.0
Co-60	0.4	0.4	0.4	0.4	1.0	1.0
Cs-137	2.0	0.5	2.0	0.5	1.0	1.0
Fe-55	40	40	40	80	1.0	0.5
Hg-203	4.0	0.9	4.0	0.9	1.0	1.0
I-125	20	2.0	20	5.0	1.0	0.4
I-131	3.0	0.5	2.0	0.5	1.5	1.0
P-32	0.3	0.3	0.3	0.3	1.0	1.0
Pt-197	20	0.5	10	0.5	1.5	1.0
Ra-226	0.3	0.02	0.2	0.02	1.5	1.0
S-35	40	2.0	40	2.0	1.0	1.0
Mo-99	0.6	0.5	0.6	0.5	1.01	1.0

Table 3. Comparison of Current and Revised A_1/A_2 values

POTENTIAL IMPACTS ON TRANSPORT PRACTICES

Preliminary information collected in the United States indicates that the reduced A_1 and A_2 values are not expected to cause significant changes in the total number and types of radioactive material packages transported annually. With a few exceptions, the changes will not impact the total activity currently transported in existing industrial, Type A, and Type B packaging designs. Most Type A package contents for medical and industrial uses are determined by user needs rather than the higher A_1 and A_2 limits. Type B packages would potentially be impacted by the reduced A-values on the allowable release limits (expressed as a fraction of A_2) but many of these are already designed to gas leak tightness in lieu of determining the actual activity release.

Medical and biotechnology packages may be impacted by changes in allowed content for excepted packages and Type A packages of ^{99}Mo-^{99}mTc. A large fraction of all excepted packages transported in the United States are standard kits used for in-vitro and in-vivo procedures. The kit contents are often the maximum allowed contents for excepted packages, generally 10^{-3} or 10^{-4} A_2. Reductions in some of the A_2 values will require shipments to be made either in a larger number of excepted packages or in Type A packages, with each option increasing transportation costs.

Shipments of ^{99}Mo-^{99}mTc Type A packages involve frequent, repetitious transport patterns as these medical isotopes are needed on a frequently recurring basis. Hand contact with these relatively high radiation level packages is the cause of most of the total dose received by transportation workers in the United States. Because the A_2 of ^{99}Mo limits the activity shipped in these packages, a reduction of the A_2 value probably would increase the number of packages shipped. This will likely result in additional packages being shipped with higher total doses being received by the drivers and handlers.

U.S. nuclear power industry shipments of low specific activity (LSA) materials and other low-level radioactive process waste are influenced by the A_1/A_2 values. Under current regulations the amount of activity allowed in industrial packages is restricted by fractions of the A_2 values allowed per gram of material. The number and types of packagings required for the LSA shipments will be changed if the A_2 values are reduced for some of the radionuclides in the wastes. Increased costs for packaging, including the use of Type B packages where the lower specific activity limits cannot be met are likely to result.

IMPACTS ON U.S. DEPARTMENT OF TRANSPORTATION EXEMPTION HOLDERS DUE TO LOWER ANNUAL OCCUPATIONAL EXPOSURE

For more than 10 years, the U.S. Department of Transportation (DOT) has authorized a limited number of highway and air carriers to carry unlimited numbers of nonfissile radioactive materials packages without regard to the sum of the transport indices of the packages (Carriker 1989). Most of the packages transported are for medical uses. The authorization requires the carriers to have formal radiation protection programs and they must provide DOT certain information that includes personnel radiation exposure results. While nearly half of the highway transport workers handling the packages receive doses greater than 5 mSv/year, only a small fraction of these workers have received annual doses in the range from 20 mSv to 50 mSv, and the remainder received less than 5 mSv/year. The ICRP 60 reduction of annual doses to 20 mSv/year (when averaged over a 5-year period) can be readily accommodated in the program for these transport workers.

Personnel operating vehicles carrying high-level and low-level radioactive waste and other shipments under exclusive use controls are not receiving radiation doses approaching 5 mSv/year according to information received from several major common and contract carriers (Schuler 1989). The low doses are not unexpected because the workers do not have close contact with the packages and the number of shipments is not great.

IMPACTS OF PROPOSED REQUIREMENTS FOR FORMAL OPTIMIZATION PROGRAMS

In the United States, the concept of formal optimization will be difficult to apply to effectively reduce radiation doses to occupationally exposed transport workers and to the public. Shippers can contribute to optimization by controlling the numbers of packages and the radiation levels of packages. However, they have economic disincentives to increasing the weight of the packages through increased shielding. The main actions that can be taken by carriers involve improving training and facilities/equipment that minimize the time and maximize the distance between personnel and the packages. However, the requirement for formal optimization programs may not be cost effective when compared with the benefits gained from simple but effective requirements for training.

ISSUES STILL TO BE ADDRESSED IN THE 1996 REVISION PROCESS

Several issues related to the revised ICRP recommendations remain to be resolved and will be further addressed during the IAEA SS No. 6 revision process. These include the following:

- Revisions to the Q-system — Changes to the Q-system, including specific consideration of chemical and physical form and the treatment of volatile liquids, must be completed and used to calculate revised A-values.
- Low Specific Activity Q-system analog (LSAQSA) — TCM-800 recommended that an LSAQSA be developed as a basis for deriving the LSA and Surface Contaminated Objects limits. While the technical committee provided some recommendations on what the LSAQSA should incorporate, the development of the models remains to be performed.
- Specification of package contamination limits — TCM-800 endorsed the current contamination limits as being reasonable, but recommended that an updated dose model be developed to provide a defensible basis for the values.
- Separation requirements — While the international transport organizations are responsible for calculating and specifying separation distance requirements, they need detailed guidance from IAEA for doing this. Reference doses and "critical groups" have yet to be recommended and need to be consistent with ICRP 60.
- Formal optimization programs — The feasibility and value of requiring formal optimization programs for all entities involved in transportation has not been

determined. In some instances, this may have a serious economic impact with unknown effectiveness in reducing doses. Alternatives, such as comprehensive training programs need to be considered.

A number of other issues were considered by TCM-800 with specific recommendations being made and the report of that Technical Committee should be consulted for further details.

SUMMARY

The recommendations of TCM-800 and the remaining issues will be forwarded by the IAEA Secretariat to the Advisory Groups, Consultants Services meetings, and Technical Committees that are a part of the 1996 revision process. While many of the most potentially disruptive issues have been successfully resolved (such as the dose limits and the Q-system reference limit), others remain to be fully addressed. Persons interested in participating in the consideration of these issues are encouraged to work with their Competent Authorities to ensure that all pertinent viewpoints are considered.

REFERENCES

Carriker, A. W., 1989. "Radiopharmaceuticals Transportation By Highway and Air-Operations and Regulatory Control," Patram '89 Symposium, Washington, D.C.

International Atomic Energy Agency (IAEA), 1982. "Basic Safety Standards for Radiation Protection (1982 Edition)," Safety Series No. 9, STI/PUB/607, International Atomic Energy Agency.

International Atomic Energy Agency (IAEA), 1990a. "Regulations for the Safe Transport of Radioactive Material (As Amended 1990)," Safety Series No. 6, STI/PUB/866, International Atomic Energy Agency.

International Atomic Energy Agency (IAEA), 1990b. "Explanatory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (1985 Edition)," Safety Series No. 7, STI/PUB/867, International Atomic Energy Agency.

International Commission on Radiological Protection (ICRP) 1990. "Annual Limits on Intake of Radionuclides by Workers Based on the 1990 Recommendations," ICRP publication 61, Pergamon Press.

International Commission on Radiological Protection (ICRP) 1977. "Recommendations of the ICRP, " ICRP publication 26, Pergamon Press.

Rawl, R. R., March 1992. "Potential Impacts of ICRP 60 and 61 on Transportation," Waste Management '92, Tucson, AZ.

Schuler, J. M., 1989. "A Comparison of Yearly Radiation Doses to Drivers from Various Types of Radioactive Materials," PATRAM '89 Symposium, Washington, D.C.