POTENTIAL IMPACTS OF ICRP 60 AND 61 ON TRANSPORTATION

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ABSTRACT

The International Commission on Radiological Protection (ICRP) has issued its "1990 Recommendations of the International Commission on Radiation Protection" that provide guidance on controlling exposure to ionizing radiation (1). The ICRP recommendations and their incorporation into the International Atomic Energy Agency's (IAEA) "Basic Safety Standards," Safety Series No. 9, provide the basis on which the IAEA "Regulations for the Safe Transport of Radioactive Materials," Safety Series No. 6, are built. The transportation regulations are developed to ensure safety during the movement of radioactive materials and to provide reasonable assurance the transportation activities comply with the basic radiation protection principles of Safety Series No. 9.

During the 1985 revision of the IAEA transport regulations, a comprehensive model was developed to derive Type A (non-accident resistant) package contents limits that were consistent with Safety Series No. 9 and, consequently, the earlier ICRP recommendations (2). Now that ICRP 60 has been published, the IAEA and Member States are faced with the task of evaluating how the transport regulations need to be revised to conform with the new recommendations. Several potentially significant issues need to be addressed to determine whether the old linkages between the recommendations and the transport regulations require modification. This paper addresses the issues that arise from the revisions to the ICRP recommendations and how the transportation regulations may be affected.

BACKGROUND

The IAEA is charged with the responsibility to foster the safe use of nuclear technology for peaceful purposes. Two aspects of this responsibility influence the international transportation of radioactive materials: the prescription of recommendations on radiation protection (Safety Series No. 9) and the regulations for safe transport (Safety Series No. 6). In the hierarchy of IAEA documents, Safety Series No. 9 provides the basic radiation protection principles with which all other Safety Series documents are expected to be consistent. Safety Series No. 6 provides the basis for all international transport regulations and is also the model for practically all Member States' national regulations (3).

The 1982 edition of Safety Series No. 9 was developed to be consistent with the existing ICRP recommendations and set the framework for subsequent Safety Series documents (2). The first subsequent revision of the transport regulations in 1985 had to take this framework into account (4). The changes that had taken place in the radiation protection recommendations were sufficient to require the development of a revised approach for providing radiation protection from Type A package accidents. This involved the development of a comprehensive model for calculating the allowable quantities of radionuclides in Type A packages. This model, known as the "Q-system," provides the basic assumptions and principles for calculating the Type A package limits for special form (nondispersible) materials, known as the A_1 value, and for normal form (dispersible) materials, known as the A_2 value.

The A-values have significant influence throughout the transport regulations. They are used as the basis for specifying:

- the maximum allowable contents (by activity) in Type A packages;
- activity concentration limits and surface contamination limits for "low specific activity" (LSA) and "surface contaminated objects" (SCO);
- activity limits for articles and packages excepted from most of the regulatory requirements; and
- allowable release limits from Type B (accident resistent) packages following imposition of the accident test conditions.

The principles of the ICRP recommendations as reflected in Safety Series No. 9 are also considered in other portions of the transport regulations, such as the need to ensure that exposures to ionizing radiation during normal transport operations are kept as low as reasonably achievable. The influence of the radiation protection principles established by ICRP and Safety Series No. 9 on the development of Safety Series No. 6 is extensive.

The IAEA and its senior transportation advisory group, the Standing Advisory Group on the Safe Transport of Radioactive Materials, have concluded that consideration of the forthcoming revision to Safety Series No. 9 (based on the ICRP changes) during the ongoing revision of the transport regulations is sufficiently important to warrant careful deliberation. A consultants services meeting and two technical committees have been scheduled to consider this topic and to provide input to the revision panels. Their input will be integrated into the development of the 1995 edition of the transport regulations.

The challenge facing the consultants and technical committees will be how to address the changes in Safety Series No.

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9 as they may apply to transport. Many of the Safety Series No. 9 standards are stated in very general terms since they must be applied in a variety of situations. The generalities must be interpreted and applied to the specific circumstances found in transport. Transport operations are very specific occurrences, but they occur in a sometimes unpredictable environment. The proximity of workers and members of the public to packages containing radioactive materials can be controlled to a large degree, but exposure to the public from low- level radiation emanating from vehicles is very difficult to accurately predict. The transport community will be faced with a number of issues that must be deliberated and decided before it can claim that the transport regulations are consistent with the new recommendations.

THE REVISED ICRP RECOMMENDATIONS

There are a number of changes in the revised ICRP recommendations (which are expected to be reflected in Safety Series No. 9) that may have direct impacts on the transportation regulations and some changes that may only have indirect impacts. Those changes which may have the most significant direct impacts include (5):

- 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 there is a probability of exposure;
- the introduction of dose and risk constraints and their recommendation as regulatory requirements;
- new radiation weighting factors for neutrons that are approximately doubled for neutrons with energy of 2 MeV and less; and
- incorporation of cosmic ray exposure into the occupational exposure calculation for aircraft crews.

The potential impacts that these changes may have on the transport regulations depends on how they are incorporated into the regulations. Such impacts are difficult to predict with much specificity at this time. The benefits that may be gained from these changes will also be difficult to determine. A trade-off between the impacts and benefits will be a major factor in determining how the recommendations should be incorporated into the regulations.

POTENTIAL IMPACTS ON THE TRANSPORT REGULATIONS

This section evaluates how the new ICRP recommendations may affect the transport regulations. The impacts that the changes in the regulations may have on transport practices is discussed in the subsequent section.

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 (6). 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. The present approach equates a number of exposure scenarios to the previously recommended dose limits.

A direct reduction of the annual dose limit from 50 mSv/year to 20 mSv/year was used by the ICRP in calculating new Annual Limits on Intake (ALI) for radionuclides (7). 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, they generally produce allowable ALI values that are 2 to 3 times lower.

The A-values that would result from a direct reduction of the annual dose limit would similarly be expected to be 2 to 3 times lower. Recent recalculations of the A-values using the Q-system (8) confirm that the expected reductions would occur with anomalies occurring as with the ALI values. The effects of this direct reduction in the dose limit on the A_2 values of 335 radionculides listed in Safety Series No. 6 include the following:

- 6.9% of the values increase;
- 6.3% of the values remain the same;
- 15.5% of the values decrease by a factor of 1 to 2;
- 61.7% of the values decrease by a factor of 2 to 3;
- 6.6% of the values decrease by a factor of 3 to 4; and
- 3.0% of the values decrease by a factor of greater than 4.

The net effect is that the A_2 value for 86.6% of the radionuclide would decrease, most by a factor between 2 and 3.

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 is based on mode-specific scenarios that assume certain geometries, distances, and durations. While the actual exposures that occur as a result of transport are generally very low, the regulatory separation distances required between packages and personnel are based on repetitive exposures. If the 1 mSv limit for public exposure is applied rigorously, the separation tables used to control normal exposures need to be recalculated and will likely result in a reduction of the allowable number of packages on a conveyance or a commensurate increase in the required separation distances.

System of Radiological Protection

The expansion of the ICRP recommendations to include limits on risks to individuals as well as limits on expected exposures from normal operations will require consideration of how the limits should apply to transport. Information on the risk of transport accidents exists in several forms and has been combined in some cases with information expected from normal operations to provide an overall assessment of the impact of transporting radioactive materials (9). Due to the difficulties of consistent data collection between Member States, an international assessment of combined normal exposures and accident risks may prove to be a significant undertaking. The

IAEA transportation experts will need to determine how this recommendation can be reasonably addressed.

Dose and Risk Constraints

The ICRP recommendations include a principle that radiation protection should optimized (kept as low as reasonably achievable) 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) so as to limit the inequity that might occur. Transport is a practice to which such constraints might apply.

Neutron Weighting Factors

The 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 2 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.

Incorporation of Cosmic Ray Exposure Into Air Crew Exposure

Current separation requirements for air crews and packages containing radioactive materials are based on a series of assumptions that allow the development of a model of their exposure during transport. The requirements are calculated on a basis of a maximum allowable contribution of 5.0 mSv/year from radioactive cargo. Consideration must now also be given to the contribution from cosmic ray exposure. It is not clear what the appropriate regulatory body is for evaluating all possible sources of exposures to air crews and for developing the appropriate controls. It is clear, however, that consideration of exposures resulting from the carriage of radioactive materials must be added to other sources.

POTENTIAL IMPACT ON HOW MATERIALS ARE TRANSPORTED

This section evaluates impacts that the changes in regulations may have on transport practices.

Reductions in Dose Limits

If radionuclides that would have significantly reduced A-values are being transported in Type A packages in quantities approaching the present A-value limits, changes would be required in the ways the materials are packaged and shipped. Either the package contents will have to be reduced and more packages will have to be transported or Type B packages will be required. If the contents are reduced and additional packages are shipped, occupational exposure will be expected to increase due to additional handling and exposure times, and additional accidents can be anticipated.

The actual impact on Type A packages is not easily discerned from looking at the reduced A-values since most Type A packages are not shipped with their contents at the Type A limit. The impact of A-value reductions is currently being investigated by the Research and Special Programs Administration of the Department of Transportation. Preliminary feedback from one radiopharmaceutical shipper indicates that, except for Mo-99, the impacts will not be significant on their activities since they typically ship materials in packages well below either the old or potentially revised Type A limits.

The "trickle down" effect that the reduced A-values will have is equally difficult to predict and must be determined by contacting shippers of LSA, SCO, and excepted packages.

Reduced occupational dose limits may affect specialized carriers that transport large numbers of radiopharmaceutical packages on a regular basis. The larger carriers in the United States operate under exemptions from the Department of Transportation that require full radiation protection programs (10). These operations involve large numbers of packages, repetitive transport and delivery patterns, and contact handling by the workers. Highway transport operations involving specialized radiopharmaceutical carriers result in some drivers (who also handle the packages during loading and unloading) receiving doses that exceed 20 mSv/year. Direct imposition of the ICRP revised occupational dose limit would require that these operations use more personnel since the current personnel exposures appear to be about as low as can be expected based on the number of packages handled. Some options for lowering the individual doses include using more drivers or separating the driving and handling functions so that different personnel receive the exposures due to driving and handling. This will have the net effect of spreading out the dose to a larger group of individuals and increasing the complexity and cost of transporting nuclear health care products.

Many transport operations result in low doses to the package handlers and conveyance operators. Large packages that are moved and loaded with heavy lift equipment generally result in low doses to the rigging crews. Dose rates in occupied areas of vehicles, aircraft, ships, and rail cars are all controlled by dose rate limits or by distance separation requirements. The effect of the ICRP revised dose limits on these operations is likely to be negligible.

System of Radiological Protection

The impact of introducing the concept of individual risk limits as well as dose limits will require that the regulations setting bodies, such as the IAEA, evaluate available information on the risks of transporting radioactive materials to see if the risks are acceptable. Considerable work has been done within individual Member States to calculate the collective risk and the potential collective and individual consequences of transport accidents. This information will need to be evaluated in light of the revised recommendations to determine if any action is needed to determine that the risk to individuals is acceptable. Since the probability and consequences of transport accidents are very low, the risk limits are unlikely to require any additional changes.

Dose and Risk Constraints

Transport is an activity that allows the accomplishment of other activities, and it does not exist as an independent activity. Consequently, the benefits and impacts of changes in how transport is performed must be considered in conjunction with other changes that may result in the activities requiring transport. For example, the impacts of further constraints on transport operations, such as lowering package dose rates,

must be considered in light of the impacts the constraints will have on the activities that require the transportation. In some cases, lowering the allowable package dose rate may result in lowering package contents but increasing the number of packages being shipped, which subsequently increases the dose to package preparers, the likelihood of a transport accident, and the dose to drivers and handlers.

The issue of "optimization" has been considered by the IAEA in several instances already. Efforts have been made to collect information from Member States that would support an evaluation of the degree to which further optimization may be needed in transport. These efforts have not lead to a definitive position from which to assess the adequacy of the present level of optimization. The addition of risk constraints to the ICRP recommendations adds another dimension to this assessment. The result is likely to compound the issue and push any resolution further into the future.

Neutron Weighting Factors

The roughly 100% increase in neutron weighting factors for energies below 2 MeV appears on the surface to have the potential for a significant impact on neutron producing materials. If applied directly and without any other influences, the increase would mean that allowable neutron fluence from packages would be halved for neutrons in this energy range. However, some investigations into the potential impact on spent fuel shipments indicate that the revisions to another standard, American National Standards Institute ANSI/ANS-6.1.1-1990, would have an offsetting effect (11). The net combined effect of the revisions to the ANSI standard and the ICRP recommendations on the spent fuel cask designs that were evaluated is a very small change in the calculated neutron dose rate.

Incorporation of Cosmic Ray Exposure Into Air Crew Exposure

Some exposures to air crews result from the transportation of radioactive materials packages aboard aircraft. The required separation distances between packages and the crew provide a limit on the dose rate that they will experience and the time of flight, and the frequency with which they are on flights carrying radioactive materials provides an overall limit on the total dose they may receive. The revised ICRP recommendations include exposure to cosmic radiation as part of their occupational exposure, which must be added to all other sources of occupational exposure for purposes of radiological protection. There is some uncertainty regarding which international governing body is appropriate for making these evaluations and determining whether additional actions are necessary. It is clear, however, that exposures resulting from transporting radioactive materials packages will now have to be considered as one component of total occupational exposure to these crews.

CONCLUSION

At this time, there is no certainty as to how the revised ICRP recommendations will be reflected in Safety Series No. 9. Even if these recommendations are adopted relatively unchanged, it is not possible to predict with certainty what the impact will be on transportation. If the existing ties between the transport regulations and Safety Series No. 6 remain the same, the effects could be substantial. A majority of A-values would decrease significantly and the "trickle down" effect on excepted packages and LSA and SCO shipments could be substantial.

There is some sentiment that the low doses and low risks associated with most transport operations provide a sufficient basis for keeping the transport regulations relatively unchanged by modifying the ties between the Q-system and other transport requirements and Safety Series No. 9 (12). In some cases, this modification simply involves evaluating the transport regulations and the expected occupational and public exposures and risks that may result and rationalizing them with the radiation protection principles. If changes to the regulations are felt to be necessary, the impact of these changes will have to be considered on a case-by-case basis. At this time, there is very little specific impact evaluation that can be performed, and, thus, only general conclusions can be drawn.

The transport community will have to address the changes in Safety Series No. 9 when they become available. Ideally, the formulation of Safety Series No. 9 will take into account input from the transport community. Since the potential for impact is significant and the transportation regulatory community will have to decide many of these issues during the current formulation of the 1995 revision of Safety Series No. 6, substantially more developments can be expected in this area.

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