ACRP Advisory Committee on Radiological
CCRP Comité consultatif de la radioprotection

ACRP-15

THE MANAGEMENT OF WORKERS OCCUPATIONALLY EXPOSED TO IONIZING RADIATION

Advisory Committees of the Atomic Energy Control Board of Canada — Secretariat: Ottawa, Canada K1P 5S9
Comités consultatifs de la Commission de contrôle de l'énergie atomique du Canada — Secrétariat: Ottawa, Canada K1P 5S9

ACRP Advisory Committee on Radiological Protection

CCRP Comité consultatif de la radioprotection

ACRP-15

THE MANAGEMENT OF WORKERS OCCUPATIONALLY EXPOSED TO IONIZING RADIATION

by the

Advisory Committee on
Radiological Protection

Approved for publication
in June 1993

Published in October 1993

An Advisory Committee of the Atomic Energy Control Board of Canada — Secretariat: Ottawa, Canada K1P 5S9

Comité consultatif de la Commission de contrôle de l'énergie atomique du Canada — Secrétariat: Ottawa, Canada K1P 5S9

PREFACE

This document is concerned with the management of all workers occupationally exposed to ionizing radiation, not just those under the jurisdiction of the AECB. The purpose of this document is to suggest a comprehensive regulatory framework for the management of occupationally-exposed workers, using the approach presented in the draft documents from IAEA (IA91a, IA91b), which incorporates the philosophy of ICRP 60 in a form that embraces the concept of safety culture. This combined approach should serve as a guide for AECB and provincial regulators now and in the future. Although both the IAEA Safety Guides (IA91a, IA91b) and the Basic Safety Standards (IA94) ignore different social and jurisdictional structures, they are applicable to all uses of radiation and can be encouraged in areas outside AECB explicit jurisdiction. This would help unify programs and management structures in all areas of radiation use. Although there is no intention of changing the jurisdiction of the provinces or the AECB, a comprehensive and integrated approach would facilitate the use of radiation for the user, and for the relevant authorities.

In general, the present document does not draw any major distinction between atomic radiation workers (ARWs) and other radiation workers, since this concept is not relevant either to the worker or to the concepts of radiation protection. Some emphasis will be placed on radiation protection in health care facilities (including radiology and nuclear medicine departments), as this is where the majority of radiation workers are found, and where the need for public access to these facilities precludes the use of engineered access control systems (such as used in nuclear power plants, AECL research facilities and uranium mines) to facilitate control and movement of personnel and radioactive sources. The highest individual doses and the largest collective dose may occur in uranium mines, but the same general principles outlined in the present document are also applicable to all facilities where workers are exposed to radiological hazards.

EXECUTIVE SUMMARY

In Canada, the regulation of radiation protection is a shared responsibility between the federal body (the Atomic Energy Control Board) and the appropriate provincial body (usually the Department of Health, or Department of Labour). The AECB is responsible, for example, for regulating the development, application and use of nuclear energy and radioisotopes, and the provinces are responsible for the regulation of all other forms of ionizing and non-ionizing radiations and for naturally-occurring radioactive material (NORM). Although there is consultation between the federal and provincial regulatory agencies, the division of jurisdictional authority has resulted in considerable differences in the approach towards implementation of radiation protection programs in Canada. This is especially true in the management of workers occupationally exposed to ionizing radiation. These differences have produced unwarranted discrepancies in operating procedures and practices, in the allocation of resources and manpower, and in the requirements governing radiological training, personnel monitoring and medical surveillance.

In light of the General Amendments to the AEC Regulations, the 1990 Recommendations of the ICRP, and the IAEA recommendations on safety culture, the ACRP has considered it timely to undertake a study to examine the feasibility of establishing a more coherent approach to harmonize radiation protection practices within Canada. This study comprised an examination of the regulatory approach used in several countries; a review of the nature of radiation safety programs in various types of licensed institutions and facilities in Canada; and a review of recommendations of internationally-recognized authorities in radiation protection.

As a result of this review, the ACRP has formulated the following recommendations:

1. Management of the radiation protection and safety programs should conform to the general principles of ICRP 60. The management structure should be applicable to all uses of radiation. (See recommendation 4.4.1.)

2. Government agencies and senior management of licensed institutions should make a firm commitment to the safety culture aspects of the radiation safety program and should provide appropriate resources. One way in which this could be promoted by the AECB is by requiring licensees, through the licensing process, to prepare both a radiation safety policy which expresses the commitment of senior management to radiation safety, and a program to implement that policy. (See recommendation 4.4.2.)

3. Workplaces where radiation is used should be classified as "controlled" or "supervised" areas. These areas should be established so that it would be highly improbable for anyone working outside a controlled or supervised area to receive a radiation dose in excess of the dose limit (1 mSv per year on average) for a member of the public, in keeping with the ICRP recommendations. (See recommendation 4.2.2.)

4. The term "Atomic Radiation Worker" should be abandoned. The term "Radiation Worker" is more suitable than "Atomic Radiation Worker" since the former term can equally well be used by all occupationally-exposed workers, regardless of the source or regulatory jurisdiction of ionizing radiation. The designation of radiation workers should be based upon the areas in which they work and the likelihood of exposure. (See recommendation 4.2.1.)

5. Appropriate regulatory bodies should give consideration to recommending a system of occupational- and source-related dose constraints. This would be in addition to the ALARA (optimization) process. (See recommendation 4.3.1.)

6. The AECB should take the lead in collaboration with other agencies, as appropriate, to coordinate a uniform application of radiation protection principles. This should include formation of appropriate federal-provincial working groups to coordinate uniform application of radiation protection principles and practices. (See recommendation 4.1.1.)

7. Any organization where occupational radiological hazards exist should be required to have a formal program of education and updating on radiation protection for radiation workers and management. The objective of radiation training for workers should be to enable them to protect themselves, their colleagues and other people in the surrounding environment. Appropriate training should also be extended to other workers who have limited or peripheral contact with radiation sources in the workplace. (See recommendation 4.4.3.)

8. All female radiation workers should be educated in respect of the potential effects of radiation on the foetus and be provided with written information. (See recommendation 4.6.1.)

9. All workers who are occupationally exposed to external radiation in controlled and supervised areas should normally be subject to individual monitoring. Exceptions may be allowed for radiation workers for whom a dose assessment clearly indicates that their doses will be consistently below the public dose limits. However, where such exceptions are made, area monitoring should be done to provide assurance that these conditions continue to be met. (See recommendation 4.5.1.)

10. Routine monitoring for internal contamination should be carried out for workers employed in controlled areas, for whom there is the possibility of intakes resulting in doses which are a significant fraction of a worker's occupational dose limit. Monitoring for internal contamination in workers who work only in supervised areas should not normally be necessary unless there are specific grounds for suspecting that intakes may have occurred. (See recommendation 4.5.2.)

11. The AECB should take the lead in developing and publishing standardized methods to detect and quantify internal contamination in workers and calculate the effective doses arising therefrom. This is particularly important in nuclear medicine, where methods for measuring internal contamination and for estimating annual intake of activity of some of the short-lived radiopharmaceuticals do not currently exist. (See recommendation 4.5.3.)

12. For reasons outlined in BMD 91-210 (AC91c), the AECB should consider one of two alternatives for pregnancy dose limits: a) Retain the pregnancy dose limits on radiation dose to the embryo or foetus that are given in the proposed 1991 General Amendments (AE91a) until such time as AECB is certain that it can overcome serious practical difficulties in demonstrating compliance with any more restrictive dose limits; or b) Alternatively, AECB could omit any special restrictions on dose limits to pregnant workers in their new regulations and insist rather on the application of the ALARA principle and permit informed workers to make their own individual choice concerning radiation exposures during pregnancy. (See recommendation 4.6.2.)

13. The AECB should support research into the determination of embryonic/foetal radiation doses due to the maternal intake of radionuclides during pregnancy. (See recommendation 4.6.3.)

14. The AECB should ensure that licensees report occupational doses from external and internal radiation sources to the National Dose Registry, and that appropriate quality assurance requirements are established for institutions providing dosimetry services. (See recommendation 4.5.4.)

15. Provincial authorities should ensure that x-ray exposures are reported to the National Dose Registry and that appropriate quality assurance requirements are established for institutions providing dosimetry services. (See recommendation 4.5.5.)

TABLE OF CONTENTS

Page

THE MANAGEMENT OF WORKERS OCCUPATIONALLY EXPOSED TO IONIZING RADIATION

1. INTRODUCTION

Soon after x-rays and natural radioactivity were discovered and put into practical use, it became evident that certain precautions were required to prevent unnecessary biological effects, such as dermatitis. The safe uses of these new tools depended to a large extent on the skill and care of the staff concerned. By 1915, the British Roentgen Society issued recommendations for the protection of "x-ray Operators" regarding correct radiation shielding. By 1921, the recommendations covered both x-ray and radium users although two of the seven guidelines for protection dealt with precautions for ventilation of the department electrical services. The term "radiation worker" started to appear in documents issued by the International Commission on Radiological Protection (ICRP) after its inauguration in 1928 and, because of the international recognition of the guidelines and practices recommended by the ICRP, the term radiation worker has been used ever since.

The advent of the nuclear age in the late 1930s led to further changes in radiation protection practices because of the increased range of available isotopes and radiations. The Canadian Atomic Energy Project (CAEP) was established in 1942 and operated in Montreal and Chalk River under the auspices of the National Research Council. The CAEP became the Atomic Energy of Canada Ltd. (AECL) in 1952. The Atomic Energy Control Board (AECB) was established in 1946 and the first regulations promulgated by this body were overwhelmingly concerned with security matters. Since health and safety matters were traditionally the concern and responsibility of the provinces, there was little reference to radiation protection. The Radiation Protection Division (RPD) of Health and Welfare Canada was formed in 1950, and this body acted as health adviser to both the AECB and the provinces, following the guidelines of the ICRP. A national film badge dose monitoring service was started by Health and Welfare Canada in 1951.

Largely consistent with the ICRP recommendations of 1959, the new Atomic Energy Control Regulations appeared in 1960. The term "Atomic Radiation Worker" (ARW) seems to spring from this time, embodying the concept of radiation worker but also implying the security aspects of those working with atomic energy.

2. THE EVOLUTION IN ICRP RECOMMENDATIONS

2.1 Dose Limits

The recommended dose limit has been reduced for workers from 50 mSv per year to an average effective dose of 20 mSv per year and for members of the general public from 5 to 1 mSv per year (IC91). This reduction was based upon the newest estimate of biological harm, which was revised partly as a result of: recent revisions in estimated radiation doses received by the Japanese bomb survivors in 1945; changes in the models used to calculate the predicted lifetime risk of fatal cancers in these bomb survivors; and other changes in radiation protection philosophy. The estimate of biological harm for effects of low-level radiation exposure on workers was thus increased three-fold from 1.65×10^{-2} Sv^{-1} in 1977 (2) to 5.6×10^{-2} Sv^{-1} in 1991 (IC91, AC91a).

2.2 The System of Protection in Occupational Exposure

In its 1990 recommendations (IC91), the ICRP stressed that the revised occupational dose limits were considered to be the dose level at which regular, deliberate, occupational exposure can reasonably be regarded as only just tolerable[1]. Equal emphasis was placed upon the principle of optimization of protection, an important feature of which was the use of dose constraints. The dose constraint is a fraction of the occupational dose limit, but which may be above the public dose limit. In most situations, operations are conducted in such a way that the standard of protection is set by the process of constrained optimization and not by the regulatory dose limits. It is important to note that even though dose constraints are set by the regulatory body after appropriate consultation with a facility (or class of facilities) or operator, these regulatory constraints are different from the prescriptive regulatory limits.

---

[1] The ICRP has found it useful to use three words to indicate the degree of tolerability of an exposure (or risk). They are necessarily subjective in character and must be interpreted in relation to the type and source of the exposure under consideration. The first word is "unacceptable", which is used to indicate that the exposure would not be acceptable on any reasonable basis in the normal operation of any practice of which the use was a matter of choice. Such exposures might have to be accepted in abnormal situations, such as those during accidents. Exposures that are not unacceptable are then subdivided into those that are "tolerable", meaning that they are not welcome but can reasonably be tolerated, and "acceptable", meaning that they can be accepted without further improvement, i.e., when the protection has been optimized. In this framework, a dose limit represents a selected boundary between "unacceptable" and "tolerable" for the situation to which the dose limit is to apply, i.e., for the control of practices. Levels of exposure that are regarded as unacceptable in this context may still be tolerable in other contexts; if, for example, they can be reduced only be abandoning a desirable practice, e.g., space missions (IC90, para. 150).

The ICRP assumed, both in 1977 and in 1990, that an annual fatality risk of 1 in 1,000 due to occupational hazards would be at the upper limit of tolerability, and that annual rates in excess of 1 in 1,000 would be unacceptable (IC77, IC91). For any given worker, this limit of 1 fatality per 1,000 workers per year would be equivalent to a 5% chance of death due to occupational hazards when summed over a working lifetime of 50 years at a continued risk of this magnitude. Radiation dose limits for workers were set with this upper limit on tolerability of occupational hazards in mind (IC77, IC91). A difference between deaths due to radiation-induced harm and those due to conventional traumatic accidents is, of course, that most radiation-induced fatal cancers are predicted to occur at age 70-80 (IC91) while traumatic fatal accidents will on average occur at about age 40. Occupational fatality rates in various Canadian industries were considered in an earlier document (AC90).

Regulatory dose constraints may be supplemented by the establishment of investigation levels for a given facility (or class of facilities) or operator. Exceeding an investigation level would require the facility or operator to implement actions (e.g., amelioration of circumstances or conditions which resulted in unplanned exposure) to redress any weaknesses in radiation protection. Finally, a given facility (or operator) may establish its own investigation levels. These reference values (or action levels) include recording levels, above which a result should be recorded, lower values being ignored; investigation levels, above which the cause or implications of the result should be examined; and intervention levels, above which some remedial action should be considered. The use of these levels can avoid unnecessary or unproductive work and can help in the effective deployment of resources. If recording levels are used, the fact that no unrecorded results exceeded the recording level should be made clear" (IC91, para 144, 238, 239, 257).

TABLE 1

Limits, Constraints and Levels

Term	Use
regulatory limit	AECB or provincial legal limit
dose constraint	special secondary regulatory limit
intervention level	level where remedial action is required
investigation level	level where a formal investigation is undertaken
recording level	level at or above which personnel or environmental monitoring data are recorded

2.3 Classification of Workplaces and Workers

In 1964, the ICRP defined a **controlled area** as one in which occupationally exposed workers might be expected to receive doses greater than 30% of the annual occupational dose limit (or 15 mSv per year). In 1977, the ICRP refined this definition of **controlled** areas by specifying that the annual doses to workers outside the controlled area be unlikely to exceed 30% of the occupational limit. The 1977 recommendations also introduced the concept of the **supervised area** beyond which it was unlikely that annual doses exceed 10% of the occupational dose limit (or 5 mSv per year). The aim of designating controlled and supervised areas was to ensure that anyone outside these areas not need be regarded as occupationally exposed. The occupational dose limits recommended by the ICRP were intended to apply to all workers, but the use of designated areas should have enabled the actual doses received outside these areas to be kept well below the public dose limits.

In the past, the ICRP defined two types of Working Conditions (A and B) based on the expected level of individual annual dose; in Working Condition A, worker doses might exceed 3/10 of the dose limits, while in Working Condition B, a

worker would be most unlikely to exceed the 3/10 level. It was, however, recognized that there was no simple parallel between the classification of areas and classification of working conditions, because the classification of areas takes no account of the time spent by workers in the area during the year, and also because conditions were rarely uniform throughout an area (IC77). For these and other reasons, Canada never adopted the use of Working Conditions A and B. In 1990, the ICRP decided that these definitions were too arbitrary and recommended that the designation of controlled and supervised areas should be decided either at the design stage or locally by operating management on the basis of operational experience and judgement, taking into account the expected level and likely variation of doses and intakes as well as the potential for accidents (IC91). The 1991 ICRP report also concluded that decisions regarding worker monitoring and medical surveillance should not be linked to a crude classification of working conditions based on expected dose and therefore recommended that the classification of working conditions A and B be dropped.

The related system of classifying workers was originally intended to help in the choice of workers to be subject to individual monitoring and special medical surveillance. In 1977 the ICRP stated that in principle, classification of workers could be done solely in terms of the working conditions in which they operated, but also acknowledged that in practice such worker classifications were usually based on a number of factors including the type of work, the area where the work was done, and an educated estimate of the time to be spent in the area (IC77).

Employees in controlled or supervised areas should be considered as radiation workers, and requirements for radiation monitoring (and medical surveillance) should be determined by licensees responsible for implementing the radiation safety program, in accordance with appropriate regulatory requirements. The designation of controlled and supervised areas should be such that anyone working outside these areas is not subject to occupational radiation exposure in excess of the public dose limit. Those who work outside these areas and receive very small doses (less than 1 mSv per year) as a result of their duties need not be regarded as occupationally exposed (IC91 para 252).

2.4 Monitoring

2.4.1 Goals and Objectives

One of the most important goals of radiological monitoring is to provide information (measurements and interpretation) required for estimating and recording the radiation exposure of workers. Secondary objectives of the monitoring program may be to ensure and demonstrate compliance with primary, derived and authorized limits, and various reference levels (recording, investigation and intervention) established locally or by regulatory agencies. The 1990 ICRP recommendations stressed the importance of properly identifying groups of workers for whom individual monitoring is required in order to optimize use of resources. Three major technical factors influence this decision: the expected level of dose or intake in relation to the regulatory limits, the likely variations in the doses and intakes, and the complexity of measurement and interpretation procedures comprising the monitoring program (IC91).

2.4.2 Monitoring External Radiation Dose

The IAEA has recently recommended that all workers who are occupationally exposed to external radiation in controlled and supervised areas be subject to individual monitoring (IA91a). Exceptions are allowed for workers for whom a dose assessment clearly indicates that their doses will be consistently below the public dose limits. When deciding whether exceptions should be made, consideration should be given to some of the secondary functions of a wider program for personnel monitoring which can provide information in support of the classification of working areas, and may prove useful as a source of data for subsequent optimization studies (IA91a).

2.4.3 Monitoring Internal Radiation Dose

The primary means of protection against internal uptakes are good work practices and appropriate protective equipment in conjunction with monitoring of work areas with contamination meters and swipes. Routine monitoring for internal contamination should be carried out for workers employed in controlled areas, for whom there is the possibility of appreciable intakes. Monitoring for internal contamination in workers who work only in supervised areas should not normally be necessary unless there are specific grounds for suspecting that intakes may have occurred, such as a transfer of contamination from a controlled area. The assessment of the need for internal monitoring should be based on a number of factors such as:

- the amount of material handled
- its chemical and physical form
- the ALI
- the manner in which the material is handled
- the probability of intake by inhalation, skin absorption and ingestion
- the results of contamination surveys.

In general, where an assessment indicates that an internal uptake could result in dose which is a significant fraction of the individual's total annual dose then individual monitoring for internal dose should be conducted.

2.4.4 Other New Issues in Monitoring

ICRP-60 (IC91) has recommended that the term occupational exposure should be extended to include all radiation exposures incurred at work as a result of situations that can reasonably be regarded as being under control of operating management. This would include the operation of jet aircraft and work places where high concentrations of radon progeny from natural sources are probable. As indicated in Annex A of the 1988 UNSCEAR report (UN88), if the annual numbers of hours spent flying in commercial jet aircraft is taken to be 600, the corresponding annual effective dose to crew members is about 1 mSv for conventional subsonic jets and about 2.5 mSv for supersonic aircraft. Workers involved in the transport of radioactive materials are not usually considered as radiation workers, although some studies have concluded that these transport workers could potentially receive doses up to 14 mSv per year. More serious problems may be encountered in non-uranium mines (not in Canada), where annual effective doses in various countries were estimated to range from 0.1 mSv to about 100 mSv, due primarily to inhalation of radon progeny (UN88). Although these categories of workers do not fall under the legal jurisdiction of the AECB, the AECB has

initiated consultation with appropriate provincial and federal agencies to implement required legislation to control the above mentioned exposures, as recommended by the ACRP (AC91a).

2.5 ALARA

For more than 30 years, the ICRP and radiation protection organizations have recommended that, in addition to regulatory dose limits, the concept of "as low as practicable" (ALAP) and "as low as reasonably achievable" (ALARA) should be applied to all occupational exposures. The decision as to what is reasonable, economic and social factors being taken into account, has generally been left to the judgement and insight of licensees. The ICRP has offered advice on optimization and decision-making in radiological protection (IC83, IC89) and the AECB Advisory Committees have also provided advice on the application of the ALARA process in the regulation of nuclear activities (AC91b). However, the majority of persons using the National Dosimetry Services work with x-ray sources and formal ALARA analyses may be difficult in this domain. For this reason, a recent document from the NCRP (NC90) on implementation of the ALARA principle for medical and dental personnel seems particularly opportune. Some of the principles outlined in this NCRP document will be noted below.

The NCRP states that the decision-making process in the optimization of radiation protection should consider both tangible data, such as the effectiveness and cost of shielding, and less tangible concerns such as impact on the quality of services performed by occupationally exposed personnel. No set of rules can be sufficiently complete to dictate the correct response to every radiation safety circumstance. This limitation is particularly evident for occupational exposure where widely disparate working environments, levels of personnel training and institutional resources are involved (NC90).

A general model for application of the ALARA process is given in a flow chart by the NCRP (NC90), which is very similar to that recommended by the ICRP. The general principles involve identification of potential problems for consideration, assessment of a particular potential problem, identification of possible responses, acquisition of optimization information for each possible response, application of the decision process, implementation of the decision, and assessment of results. However, the NCRP stresses that "the intent of this approach is to give guidance on how an individual institution might develop its own method rather than to impose a particular method on the medical radiation safety program. Adaptation to local operations, costs, capabilities and social factors is the essence of implementing ALARA" (NC90). The same general principles should be considered in implementation of the ALARA process in other non-medical institutions.

2.6 Medical Surveillance

A brief review of ICRP recommendations dating back over 30 years shows that the aims underlying health or medical surveillance of workers exposed to radiation are based on basic general principles of occupational medicine. The purposes of medical surveillance were "to assess the health of the worker, to help in ensuring initial and continuing compatibility between the health of workers and the conditions of their work, and to develop a baseline of information useful in the case of accidental exposure or occupational disease" (IC77).

In 1962, the ICRP recommended that all new personnel in radiation work should have a pre-employment medical examination, and that subsequent routine medical examinations be performed at a frequency depending on the conditions of the occupational exposure (IC64). In 1965, the ICRP recommended special medical supervision and individual monitoring for those workers receiving doses in excess of 3/10 of the annual dose limit; for those receiving lower doses, neither individual monitoring or health supervision was required (IC66). As a specific example of determining fitness for the job, in 1977 the ICRP recommended that uranium workers undergo pre-employment medicals for detailed evaluation of lung function, and to ascertain any pre-existing or chronic bronchial or lung diseases (e.g., healed tubercular lesions of large extent) where the particular hazard of exposure to radon daughters should preclude this sort of work (IC77a). In another 1977 publication, the ICRP recommended that medical radioisotope workers subject to greater than 3/10 of the annual dose limit (15 mSv effective dose) be given a pre-operational medical examination before starting that type of work (IC77b) and that consideration be given to the need for continuing surveillance of the health of workers, at the discretion of the occupational physician. However, it was also noted that deleterious health effects are unlikely to be detected following exposures within the dose limits, and that "medical surveillance has no part to play in confirming the effectiveness of a radiation protection program" (IC77). In 1991, the ICRP stated that the primary purpose of the occupational health service was to decide on the fitness of each worker for the intended tasks, and further indicated that the radiation exposure component of the working environment will only very rarely have any bearing on the assessment of the workers fitness. It was further recommended (IC91) that an occupational health service be available to counsel occupationally exposed workers who:

(i) have become pregnant,

(ii) have been exposed substantially in excess of the dose limits or who have been involved in potentially dangerous situations,

(iii) are considering volunteering for deliberate exposures as part of biomedical research programs.

It should be noted that, in Canada, current regulatory requirements for medical surveillance of atomic radiation workers do not wholly embrace the ICRP recommendations. Guidelines for medical surveillance of radiation workers were first published in 1991 by the AECB's Group of Medical Advisers (GM91) and were subsequently revised in 1993 (GM93a). Information on current practice of medical surveillance in various Canadian industries is presented in Appendix II of this report.

3. DISCUSSION OF CANADIAN PRACTICES

3.1 Jurisdiction

In Canada, the regulation of radiation protection is a shared responsibility between the federal body (the Atomic Energy Control Board) and the appropriate provincial body (usually the Department of Health, or Department of Labour). Although there is considerable consultation between the federal and provincial regulatory agencies, the division of jurisdictional authority has contributed to the creation of undesirable differences in the approach towards implementation

of radiation protection programs in Canada. Table 3 summarizes some of the more significant differences. This subject is also addressed in greater detail below.

3.2 AECB Definition of Atomic Radiation Workers

Recent Atomic Energy Control (AEC) Regulations (AE88) defined an atomic radiation worker (ARW) as any person who in the course of his work, business or occupational is likely to receive a whole-body dose of ionizing radiation in excess of 5 mSv per year (with other specified limits for individual tissues) or an exposure to short lived radon progeny in excess of 0.4 WLM per year. The limits on occupational exposure of an ARW were set at 50 mSv per year or 4 WLM per year (AE88). This definition applied specifically to persons working in a nuclear facility, as defined by the AECB, and where deemed necessary to other licensees working with radioactive materials. In theory, this would mean that a total dose limit of about 100 mSv per year for combined exposures to external radiation plus inhaled radon progeny (Ch84).

The AEC Regulations did not apply to persons working with other radiation sources, e.g., x-ray machines, or to persons working in those mines with concentrations of radon progeny which are not specifically mining uranium or thorium. These latter groups fall under provincial jurisdictions. Medical and dental x-ray personnel probably account for about 70% of the persons listed in the National Dose Registry of Health and Welfare Canada. The difference between the federal AECB and the provincial regulatory authorities depends on the question of legal jurisdiction, even though the source of the radiation exposure does not make any difference to the exposed worker. However, for persons who are exposed to both gamma and x-ray radiation, the AECB uses the total exposure as the basis of any actions. In addition, most provincial regulations governing radiation exposure limits parallel closely the regulations for ARWs as defined by the AECB.

The AEC Regulations (AE88) were based on ICRP recommendations published in the 1960s and vaguely incorporated the 1977 recommendations (IC77) concerning addition of radiation doses from external and internal sources. This weakness has been addressed in the new General Amendments to the AEC Regulations (AE91a) which are expected to become law.

An ARW is recently defined as "a person who is required ... "to perform duties in such circumstances that there is a reasonable probability that, during a dosimetry year, the person may receive a dose of radiation greater than ... 5 mSv, where the dose of radiation is the aggregate of (i) the effective dose received by the person from external sources of radiation during the dosimetry year, and (ii) the committed effective dose from all radioactive prescribed substances that enter the body of the person during the dosimetry year" (AE91a). Other specified limits for individual tissues are provided. The limits on occupational exposure of an ARW were set at an aggregated effective dose of 50 mSv per year. The aggregate effective dose for uranium and thorium miners includes doses received from external sources, from inhalation of radon and thoron progeny, and from inhalation of long-lived radioactive dust. The distinction between workers under federal and provincial jurisdictions would remain as before.

In Consultative Document C-122, the AECB proposed that an ARW "be defined as a worker with a reasonable probability of receiving more than 1 mSv per year" (AE91b). Because of this new definition, some workers will now become ARWs who

previously were not. However, the AECB has clearly indicated that this should not be construed as a relaxation in dose control for these workers (i.e., their dose limit changing from 5 mSv to 20 mSv per year) (AE91b). Individual and collective occupational radiation doses should be continually reviewed and justified. Occupational exposure should be optimized by applying the ALARA concept "doses should be as low as reasonably achievable, economic and social factors taken into account."

To date, there has been considerable inconsistency in the approach used by AECB licensees to designate their atomic radiation workers. This situation is possibly due to varying philosophies held by radiation protection managers in different industries and is discussed further below.

3.3 Uranium Mines and Mills

Each licensee draws up its own plans which are designed to meet provincial (as well as federal) requirements on health protection of miners. In general, most employees (except some administrative staff who never enter the mine or mill) are designated as ARWs. Radon progeny are frequently measured by the traditional method of grab sampling for area monitoring, although some mines in Saskatchewan use the personal dosimeters developed by the CEA. Whole body doses from external radiation are measured using the TLD service provided by the Bureau of Radiation and Medical Devices (BRMD) in Ottawa. BRMD data includes both radon progeny and TLD readings in the National Dose Registry. There does not seem to be any regular monitoring of exposures to uranium ore dust, although this has been carried out in a number of mines and will become compulsory when new AEC Regulations on the combined exposure formula come into effect. Regular urinalysis for inhaled or ingested uranium is not required for uranium miners.

3.4 Uranium Refineries

The Port Hope refinery designates as an ARW every person in the uranium processing plant excepting some secretaries and administrative staff. All ARWs and other personnel have their whole-body radiation doses monitored every two weeks with TLD badges issued by BRMD, and the facility also utilizes BRMD TLD ring dosimeters to measure extremity doses. Exposure to uranium and fluoride is monitored by a routine weekly urinalysis program, and internal lung contamination in workers is measured by means of an on-site lung counter. All ARWs undergo a strict regimen of routinely scheduled medical examinations as well as pre-employment and termination medicals. The company has conservative dose limits (based on two-week and 3-month (quarterly) monitoring periods) for external exposures to women of reproductive age, and has not adopted the less restrictive 1985 AEC revised regulation on the exposure limits for non-pregnant female workers. Women are required to report their pregnancies immediately upon diagnosis, at which time they are removed from all work involving radiation exposure (Ca91).

3.5 Nuclear Power Plants

All permanent workers on the site of nuclear generating stations in Canada are designated as ARWs (with the exception of one utility, where a number of administrative personnel are not so designated because of the physical layout of the plant). ARW status is also required for all other persons (consultants,

TABLE 2

BREAKDOWN OF WHOLE BODY DOSE EQUIVALENTS (mSv) TO CANADIAN WORKERS BY OCCUPATION (1991)*

OCCUPATION	NUMBER OF WORKERS IN EACH INTERVAL							TOTAL NUMBER	AVG DOSE	AVG OF DOSES >0.2 mSv
	<0.2 mSv	0.2-1 mSv	1-2 mSv	2-5 mSv	5-10 mSv	10-20 mSv	>=20 mSv			
ADMINISTRATIVE:										
ADMINISTRATOR	23	3	0	1	1	0	0	28	.53	2.96
OFFICE STAFF	2866	594	143	12	6	3	0	3624	.18	.84
SAFETY OFFICER	15	9	0	3	0	0	0	27	.58	1.29
MEDICAL:										
CHIROPRACTOR	730	61	4	1	0	0	0	796	.03	.39
DENTAL HYGIENIST	5638	94	3	1	0	0	0	5736	.01	.34
DENTIST	5061	100	2	0	0	0	0	5163	.01	.31
GYNAECOLOGIST	25	3	0	0	0	0	0	28	.03	.23
NUCLEAR MEDICINE TECHNICIAN	372	322	254	300	38	1	1	1288	1.32	1.86
LABORATORY TECHNICIAN (MEDICAL)	2459	496	32	20	3	3	1	3014	1.27	6.87
MEDICAL PHYSICIST	175	59	5	5	0	0	0	244	.18	.62
NURSE	3604	657	23	7	2	0	0	4293	.06	.40
PHYSICIAN	1420	396	53	16	6	2	1	1894	.18	.73
RADIOLOGICAL TECH (DIAGNOSTIC)	8043	1941	118	62	4	0	1	10189	.10	.46
RADIOLOGICAL TECH (THERAPEUTIC)	374	301	58	26	4	1	0	764	.42	.82
RADIOLOGIST (DIAGNOSTIC)	1186	403	33	20	1	0	0	1643	.15	.55
RADIOLOGIST (THERAPEUTIC)	105	34	6	5	3	0	0	153	.38	1.21
VETERINARIAN	1416	256	16	5	1	1	0	1695	.08	.47
WARD AID/ORDERLY	1364	166	9	6	2	0	0	1547	.06	.51
INDUSTRY:										
FUEL PROCESSOR	14	12	4	11	8	2	0	51	2.45	3.38
INDUSTRIAL RADIOGRAPHER	730	288	152	212	179	122	45	1728	3.05	5.28
INSTRUCTOR (NON-MEDICAL)	85	26	5	1	0	0	0	117	.16	.58
INSTRUMENT TECHNICIAN	820	320	66	26	17	7	0	1256	.40	1.15
LABORATORY TECHNICIAN (INDUSTRIAL)	3210	638	114	64	30	4	1	4061	.21	1.00
SCIENTIST ENGINEER (FIELD)	460	250	102	37	21	9	1	880	.80	1.66
SCIENTIST/ENGINEER (LABORATORY)	2720	650	114	19	8	0	0	3511	.15	.65
WELL LOGGER	225	340	171	117	18	4	2	877	1.11	1.49
POWER STATIONS:										
REACTOR - ADMINISTRATION	3060	164	48	36	8	3	0	3319	.11	1.36
REACTOR - CHEMICAL AND RADIATION CONTROL	216	88	43	58	26	28	12	471	2.46	4.50
REACTOR - CONSTRUCTION	3100	364	159	201	118	25	0	3967	.56	2.53
REACTOR - CONTROL TECHNICIANS	107	27	18	12	4	3	0	171	.84	2.20
REACTOR - ELECTRICAL MAINTENANCE	664	242	130	135	53	2	0	1228	.92	1.99
REACTOR - FUEL HANDLING	16	5	14	7	15	4	0	61	3.30	4.47
REACTOR - GENERAL MAINTENANCE	933	192	94	89	41	5	0	1354	.67	2.09
REACTOR - HEALTH PHYSICS	88	24	5	4	0	0	0	121	.30	1.07
REACTOR - MECHANICAL MAINTENANCE	487	303	159	303	223	46	0	1521	2.37	3.47
REACTOR - OPERATIONS	738	382	216	255	115	34	3	1743	1.52	2.62
REACTOR - SCIENTIFIC/PROFESSIONAL	1018	139	51	47	27	7	0	1289	.45	2.06
REACTOR - TRAINING	63	8	0	2	0	0	0	73	.15	1.04
REACTOR - VISITOR	8	5	2	3	2	0	0	20	1.43	2.37
MINING:										
MINERS	608	439	244	207	56	9	2	1485	1.17	1.79
MISCELLANEOUS:	39417	6368	1055	728	329	208	80	48185	.28	1.53

* special analysis of 1991 data courtesy of W. Sont & P. Ashmore, BRMD, National Dose Registry
** includes whole body exposures to gamma radiation only. Uranium miners are also exposed to radon progeny and other radiation sources.

TABLE 3

SUMMARY OF CURRENT CANADIAN PRACTICES FOR MANAGEMENT OF OCCUPATIONALLY EXPOSED WORKERS

	MEDICAL: HOSPITALS & CLINICS	EDUCATION: UNIVERSITIES & COLLEGES	AECL FACILITIES	NUCLEAR POWER STATIONS	URANIUM MINES & MILLS	URANIUM REFINERIES	INDUSTRIAL RADIOGRAPHY
ACCESS	Public	Public	Restricted	Restricted	Restricted	Restricted	Restricted where possible
JURISDICTION	AECB/Provinces	AECB/Provinces	AECB	AECB	AECB	AECB	AECB
WORKER DESIGNATION 1. No exposure 2. <5 mSv/yr 2. >5 mSv/yr	 Public Public ARW & Public	 Public Public ARW & Public	 ARW ARW ARW	 ARW ARW ARW	 No ARW ARW	 ARW ARW ARW	 ARW ARW ARW
MONITORING: 1. Individual TLD 2. Bioassay	 Occupationally exposed employees As required (only radioiodine & tritium)	 Occupationally exposed employees As required (only radioiodine & tritium)	 All employees As required	 All employees As required	 Occupationally exposed employees As required Weekly (uranium)	 All employees As required	 All employees plus direct reading dosimeter None
MEDICAL SURVEILLANCE: AECB Requirement? WHEN: 1. Pre-employment 2. Routine periodic 3. Termination	 No Yes (immunization record) No No	 No No No No	 No Yes Yes Yes	 No Yes Yes Yes	 Yes Yes Yes No	 No Yes Yes Yes	 None
PREGNANT WORKERS:	Continue radiation work with added precautions (exception: some Quebec hospitals)	Continue radiation work with added precautions	Removed from radiation work	Removed from most radiation work	Removed from all radiation work	- Few women - Removed from all radiation work	Few women involved
TRAINING	Variable - Training at professional level is often assumed	Variable	Basic Training Program	Comprehensive Training Program	Basic Training Program	Basic Training Program	Qualified Operator Exam Required

Table 4

EXAMPLES OF ANNUAL OCCUPATIONAL RADIATION EXPOSURES IN 1991 TO HOSPITAL, RADIOPHARMACY AND NUCLEAR MEDICINE WORKERS IN MANITOBA AND QUEBEC

Institution	Maximum Dose (mSv)	Dose Range (mSv)	Collective Dose (mSv)	# of Persons	Average Dose (a) (mSv)
Central Radiopharmacy	10.5	3.7 - 10.5	35.1	5	7.0
University Hosp. #1 (b)	3.9	0.5 - 3.9	17.8	11	1.6
University Hosp. #2 (b)	2.6	0.6 - 2.6	9.0	8	1.1
University Hosp. #3 (d)	1.2	0.5 - 1.2	55.2	115	0.5
Community Hosp. #1 (b)	1.3	0.2 - 1.3	2.1	3	0.7
Community Hosp. #2 (b)	0.2	0 - 0.2	0.6	4	0.15
Community Hosp. #3 (b)	0.8	0.8	0.8	1	0.8
Regional Hospital (c)	4.9	0.3 - 4.9	13.3	5	2.7
Hospital A	4.2	-	19.8	15	1.3
Hospital B	4.0	-	26.6	14	1.9
Hospital C	4.2	-	41.4	18	2.3
Hospital D	8.0	-	47.3	11	4.3
Hospital E	4.8	-	1.6	4	0.4
Hospital F	8.6	-	79.2	33	2.4
Hospital G	4.5	-	-	-	2.3
Hospital H	12.2	-	37.1	7	5.3
Private Clinic #1 (c)	4.8	1.2 - 4.8	9.1	3	3.0
Private Clinic #2 (c)	0.9	0.2 - 0.9	2.5	5	0.5

Notes:

(a) collective dose divided by the total number of workers monitored during the year, including workers hired on a casual or part-time basis.

(b) received daily shipments of ^{99m}Tc radiopharmaceuticals (in vials) from central radiopharmacy.

(c) purchased ^{99}Mo/^{99m}Tc generators for in-house radiopharmaceutical production.

(d) research technicians who are classified as ARWs because they are involved in radioiodination.

visitors required to do radiation work, etc.) who may during their stay receive doses approaching or in excess of dose limits for non-ARWs. Prospective employees must be at least 18 years old and are required to pass a thorough medical examination prior to employment. Once hired, workers are subject to periodic routine medicals every two to four years, although the need for the periodic medicals is under review. Special medical examinations may be ordered by the plant's Health Physics Group as required after overexposures, etc.

All workers and visitors entering any radiological zone at nuclear stations wear biweekly TLD badges at the very minimum. In zones rated with a higher probability of exposure, direct reading dosimeters must also be worn. If necessary, neutron dosimeters are worn. When it is anticipated that the dose to the worker's hands will be higher than that registered on the TLD badge or direct reading dosimeter, extremity dosimeters are also used. Appropriate bioassay procedures for dosimetry purposes is carried out in accordance with the level of risk of internal contamination.

When a female worker declares her pregnancy (as required by AECB regulation and plant policy), her job assignment is evaluated for radiation risks, and she undergoes counselling to determine whether there are any psychological concerns. Pregnant women are subject to a biweekly dose limit of 0.6 mSv and are not allowed to work at all in zones where there is a potential for exceeding the legal dose limit for pregnant workers. Pregnant women may continue to perform non-radiological tasks in zones where the ambient dose rate is relatively low, but if a worker appears troubled by the prospect of continuing work in a radiation environment during the remainder of her pregnancy, she will be reassigned to another area where her tasks will involve no occupational radiation exposure (Rh91).

3.6 AECL Research Facilities

Regardless of their actual potential for occupational exposure, AECL workers (even cafeteria staff) are automatically designated as ARWs, and are subject to the close medical surveillance common to nuclear power plants. Employees automatically undergo medical examinations shortly after employment and are also subject to routine periodic and termination medicals. All workers wear TLD badges and if necessary, extremity dosimeters, and undergo appropriate bioassay for the radionuclides in use in the workplace if activity levels handled warrant such measurements. Female workers are removed from the radiation work environments after declaring pregnancy and are given work assignments that do not involve appreciable radiation exposure (My91).

3.7 Hospitals and Medical Clinics

The medical workplace commonly has a wide range of ionizing radiation sources available for diagnosis and treatment. These include both various x-ray installations and unsealed radioactive materials handled in nuclear medicine departments, radiopharmacies and radiotherapy facilities. In addition, many clinical and medical research laboratories utilize radioactive tracers for in vitro studies. The AECB's jurisdiction includes radioactive sources used in nuclear medicine and other laboratories. In radiotherapy facilities, the AECB licences brachytherapy and teletherapy radiation sources, excluding low-energy accelerators which are under provincial jurisdiction, along with all x-ray equipment.

3.7.1 Administrative Aspects

The administrative aspects of radiological protection can be complex in a hospital and there may be three or more responsibility centres involved. For example, the x-ray department typically assumes responsibility for its own equipment. Radiation protection aspects of brachytherapy are supervised by the medical physics department of the cancer clinic, often located outside the hospital (AE87). The nuclear medicine department operates under an AECB radioisotope licence, which is administered by a RSO (who may be a nuclear medicine technologist, a nuclear medicine physician or a medical physicist). The clinical laboratory department (biochemistry, haematology, etc.) may perform in vitro radioimmunoassay procedures under a second AECB licence for which the medical director of the laboratory is designated as the RSO. A Joint Workplace Health and Safety Committee (JWHSC) comprised of both management and union representatives, is required by provincial (and federal) labour laws. The JWHSC is concerned with a myriad of occupational safety and health issues which can occasionally involve radiological hazards. Formal communication links between the JWHSC and various responsibility centres outlined above often are not in existence.

3.7.2 Medical Surveillance of Medical Workers

Most hospital workers in Canada, regardless of their potential for occupational radiation exposure, undergo a brief medical examination shortly after being hired. The examination usually consists of obtaining a medical history; the primary purpose being to ensure that appropriate immunizations for communicable diseases are up-to-date. Generally, there is no extraordinary regimen of periodic or termination medical examinations for those who are occupationally exposed to radiation (Ya91).

3.7.3 Radiation Dose Monitoring in Health Care Facilities

Most provincial legislation requires the operators of x-ray machines to wear TLD badges, even though the vast majority (88%) of x-ray technologists, diagnostic radiologists, chiropractors, dentists, and dental hygienists had no measurable radiation exposure in 1990 (As93). Examples of occupational exposures of university, radiopharmacy and nuclear medicine workers in various Canadian locations are listed in Table 4.

Up until quite recently, standard AECB radioisotope licences issued to medical institutions specified that any person working with a radioactive prescribed substance be issued with a quarterly TLD badge. Radioisotope workers handling more than 50 MBq of high energy beta emitters were required by licence conditions to wear ring dosimeters. Pregnant ARWs and some ARWs in high dose-rate environments were issued biweekly TLD badges and personal digital dosimeters, if available. As a result, virtually all radiotherapy, nuclear medicine and radioisotope laboratory personnel were issued TLD badges. Workers handling radioiodines were subject to AECB Regulatory Document R-58 which specifies bioassay requirements for iodine-125 and iodine-131 (AE83).

Since 1991, radioisotope licences specify that ARW monitoring requirements be performed in accordance with AECB Regulatory Document R-91 (titled "Monitoring and Dose Recording for the Individual", (AE90)) which requires that TLDs be worn in such a way to measure doses from external beta and gamma radiation. R-91 also

deals with non-ARW occupationally exposed persons by requiring personal monitoring (TLD badge) for any worker likely to accumulate 10% of the annual ARW dose limit (currently set at 50 mSv). R-91 provides the employer with the discretion to use either personal or non-personal monitoring methods to confirm doses to those workers who receive less than 10% of the ARW annual dose limit.

R-91 also requires that AECB-approved bioassay methods be used, if necessary, to estimate doses from internal contamination. Bioassay procedures are currently carried out only for two radioiodine isotopes in most Canadian medical facilities (AE83).

3.7.4 Other Workers

In a hospital, many workers (e.g. nurses, attendants, and porters) receive very small doses of radiation from patients injected with radioactive materials. Some workers may also receive occasional small doses when assisting patients undergoing x-ray examinations. The majority of these workers are not issued TLD badges and currently receive very little or no radiation protection training, which has led many of them to manifest concerns about their safety.

3.7.5 Designation of ARWs

Historically, AECB licensees have been somewhat inconsistent in the approach used to designate ARWs. This is especially the case in Canadian medical institutions. For example, in one institution, a few nuclear medicine workers routinely receive annual doses in excess of 5 mSv, although none are designated as ARWs. This situation is uncommon and is a clear violation of the AEC Regulations which could result in prosecution or regulatory action. However, there is a general reluctance for some hospital workers and unions to accept ARW designation, because they feel "protected" by the 5 mSv dose limit for members of the public. There is a common perception, albeit anecdotal, that accepting the ARW designation might result in a worker receiving a higher occupational dose because the employer might relax radiation protection practices and application of ALARA. In another institution, the responsibility centres charged with radiation protection have simply designated as ARWs most nuclear medicine, radiopharmacy and radiotherapy workers. This practice was carried out regardless of actual dose received, solely for administrative ease. All persons designated as ARWs under this approach have the "potential" to exceed 5 mSv annually, although only a few (central radiopharmacy) workers actually receive doses above 5 mSv.

3.7.6 Pregnant Medical Workers

A pregnant woman who is aware of her pregnancy before she is hired as an atomic radiation worker is required under AEC Regulations to inform her employer, on being hired, that she is pregnant. Similarly, a woman who becomes pregnant after she is hired as an atomic radiation worker is required to inform her employer of her pregnancy as soon as she becomes aware of it. Under current AECB regulations, once pregnancy is declared, the pregnant ARW is subject to a dose limit of 10 mSv to the surface of the abdomen for the remainder of the pregnancy and a supplementary dose-rate limit of 0.6 mSv in any two-week period. In light of the 1990 ICRP recommendations, the AECB has proposed to lower the radiation dose limit to the pregnant worker's abdominal surface to 2 mSv from external radiation sources, and further to restrict internal radiation exposure to 1/20th of the annual limit on intake (AE91b). These dose limits would apply to the worker once

pregnancy is declared. Failure to base decisions on radiation protection principles and on valid occupational health and safety concerns has led to certain situations where hospital radiation workers have been removed from work and put on paid leave. This is inconsistent with practices in most areas of Canada.

Once the pregnancy is declared, an assessment of the individual's exposure history and work assignments should be undertaken with the goal of minimizing occupational radiation exposure for the remainder of the pregnancy. With few exceptions, occupationally exposed medical workers can continue to work during pregnancy since in practice most pregnant nuclear medicine technologists receive far less than 1.0 mSv of external occupational exposure during pregnancy. Consideration should be given to work transfers or reassignment to low-dose areas, provision of additional personal monitoring (by issuing TLDs for two-week monitoring periods and a personal digital dosimeter, if available). Most pregnant medical workers should be prohibited from handling radioiodines, because of the potential for foetal exposures following accidental maternal ingestion or inhalation.

3.8 Universities and Community Colleges

Many post-secondary educational institutions hold consolidated AECB radioisotope licences to cover teaching and research uses (usually in vitro and animal studies) of radioactive materials. The quantity of radioactivity handled and concomitant occupational radiation exposure is usually much smaller than in medical facilities. Very few university radioisotope workers are designated as ARWs, although most are issued quarterly TLD badges from the BRMD and also wear ring TLDs if working with more than 50 MBq of high-energy beta emitters. Depending on the activity levels handled, radioisotope workers undergo bioassay for radioiodines and tritium in accordance with AECB regulatory documents. Many of the items discussed in the above section on health care facilities apply equally to the post-secondary educational institution. The one significant difference is that all health and safety operations (including radiological safety) in the institution are usually under the control of a central safety office, which has considerable advantages in terms of communication, integration and implementation of various occupational safety programs.

4. ISSUES: BACKGROUND, DISCUSSION AND RECOMMENDATIONS

4.1 ISSUE #1: *Regulatory Approach*

Background

In Canada, the regulation of radiation protection is a shared responsibility between the federal body (the Atomic Energy Control Board) and the appropriate provincial body (usually the Department of Health, or Department of Labour). The AECB is responsible for regulating the development, application and use of nuclear energy and radioisotopes, and the provinces are responsible for the regulation of all other forms of ionizing and non-ionizing radiations. Although there is consultation between the federal and provincial regulatory agencies, the division of jurisdictional authority has contributed to the creation of undesirable differences in the approach towards implementation of radiation protection

programs in Canada. This is especially true in the management of workers occupationally exposed to ionizing radiation.

Discussion

The AECB has historically been responsible for regulating the use and development of nuclear energy and radioactive isotopes and linear accelerators above 10 MVp; the provinces have been responsible for everything else, including naturally-occurring radioactivity. For these and other reasons, quite different levels of safety programs now exist in the use of radioactive isotopes compared to other sources of ionizing radiation. These safety programs vary between different provinces and between different industries, as outlined in Section 3. For instance, the nuclear power utilities often have excellent safety programs, with good resources in staff and equipment. In other sectors, such as university research centres and hospitals, resources for training and radiation safety resources may be limited or non-existent.

Historically, the AECB has set the standard in dose limits which are likely to be adopted over time in the provinces for other radiation emitting devices and for naturally-occurring radiation. With the publication of ICRP 60 (IC91), the time has arrived for Canadian regulatory agencies to unify the management of radiation protection across the country. It is very important therefore that both the AECB and the provincial regulatory agencies adopt the philosophy of ICRP 60. The current approach of the ICRP towards the management of safety programs, designation of working areas and personnel, training, and dose limitation is applicable to all uses of radiation.

Recommendations

4.1.1 The AECB should take the lead in collaboration with other agencies, as appropriate, to ensure uniform application of radiation protection principles. This should include formation of appropriate federal-provincial working groups to coordinate uniform application of radiation protection principles and practices.

4.2 ISSUE #2: *Classification of Workplaces and Workers*

Background

In 1964, the ICRP had defined a **controlled area** as one in which occupationally-exposed workers could receive doses greater than 30% of the annual occupational dose limit (or 15 mSv per year). In 1977, the ICRP refined this definition by specifying that the annual doses to workers **outside** the controlled area be unlikely to exceed 30% of the occupational limit. The 1977 recommendations also introduced the concept of the **supervised area** beyond which it was unlikely that annual doses exceed 10% of the occupational dose limit (or 5 mSv per year).

The ICRP stated that in principle, classification of workers could be done solely in terms of the working conditions in which they operated, but also acknowledged that in practice such worker classifications were usually based on a number of factors including the type of work, the area where the work was done, and an educated estimate of the time to be spent in the area (IC77).

In 1990, the ICRP concluded that decisions regarding worker monitoring (and medical surveillance) should not be linked to a crude classification of working conditions based on expected dose and therefore recommended that the classification of working conditions A and B be dropped. The ICRP also decided that earlier definitions of supervised and controlled areas were too arbitrary and recommended that the designation of controlled and supervised areas should be decided either at the design stage or locally by operating management on the basis of operational experience and judgement, taking into account the expected level and likely variation of doses and intakes as well as the potential for accidents (IC91).

Discussion

Employees in controlled or supervised areas should be considered as radiation workers, and requirements for radiation monitoring (and medical surveillance) should be determined by licensees responsible for implementing the radiation safety program, in accordance with appropriate regulatory requirements. The designation of controlled and supervised areas should be such that persons working outside these areas are not subject to occupational radiation exposure in excess of the public dose limit. Workers who work outside these areas and receive very small doses (less than 1 mSv per year) as a result of their duties should not be regarded as occupationally exposed workers.

Workplaces where radiation is used should be identified and classified on a consistent[2] basis, regardless of the type of institution and regardless of the regulatory jurisdiction. This should be done on the basis and nature of the radiological hazards present; and on the likelihood (or level) of occupational exposures. Workplaces should be classified as "controlled areas" or as "supervised areas" (see below) and the radiation protection officer should be involved in designating these areas.

Controlled Area - is any area where special considerations are needed to control occupational exposures or to prevent the spread or dispersal of radioactive contamination to other areas. The extent of the controlled area shall be determined by taking into account the magnitude of the expected exposure of employees working in the control area and the likelihood of accidental exposures.

Supervised Area - is an area not already designated as a controlled area where working conditions should be kept under review even though specific radiation protection procedures are not usually required. *Radiation protection measures commensurate with the level of risk in the supervised area should be established within the framework of the radiation protection program.*

---

[2] The AEC Regulations have resulted in effecting a degree of consistency by requiring all licensees to post a radiation hazard sign *whenever the dose rate exceeds 25 $\mu Sv.h^{-1}$ or an area contains more* than 100 scheduled quantities. In addition, the AECB has specific requirements for laboratories based upon the activity and isotopes used.

The whole question of the designation of occupationally exposed workers in Canada needs to be re-examined for several reasons:

i) At present at Atomic Radiation Worker is defined as "a person who is required to perform duties in such circumstances that there is a reasonable probability that, during a dosimetry year, the person may receive a dose of greater than 5 mSv ....". This definition, or previous similar definitions under previous regulations, has led to an inconsistent approach to the designation of ARWs. There are some institutions who designate all staff as ARWs regardless of their likelihood of radiation exposure, and at the other extreme there is at least one institution that does not designate staff as ARWs even though doses are exceeding 5 mSv per year. Clearly neither practice is acceptable and may even contravene the AEC Regulations. In health care and research institutions the situation may be further complicated as workers may be exposed to radiation from radionuclides and from radiation emitting devices.

   It is suggested in ICRP 60 (IC90) and in IAEA (IA91a) that staff be classified according to the type of risk in the areas where they work. Those that work in controlled or supervised areas should be designated as 'radiation workers'. This approach should rectify the inconsistencies in the present system.

ii) In the proposed regulations, an ARW will be a person who may receive an occupational dose in excess of the public dose limit. Since the proposed public dose limit (C-122) will be 1 mSv per year, this makes personnel dosimetry very difficult in practice, although it is possible to measure 1 mSv per year in a laboratory using current dosimetry systems. The designation of ARWs based upon measured personal annual dose may therefore have less meaning.

iii) With the new public dose limit of 1 mSv more people will be designated as ARWs. From the data in the National Dose Registry in Table 2 it will be evident that nearly 8300 persons received between 1 and 5 mSv in 1991, and almost 16,000 persons received between 0.2 and 1 mSv. Many of these workers come under AECB jurisdiction and difficult decisions will have to be made as to whether they will have to be designated as ARWs (if they are not already). The definition of radiation workers based upon the workplace as suggested above would make this task much easier.

iv) The term Atomic Radiation Worker comes from the very early days of atomic power in Canada and 'atomic' was used to indicate the security aspects of the work. This no longer applies to current radiation workers and the term which is used in all other parts of the world - 'radiation worker' - is preferable.

   Under the new regulations many of the newly designated ARWs will be health care workers to whom the term 'atomic' has only bad connotations.

v) In many industries radiation exposure comes from both radionuclides and radiation emitting devices. If the name 'radiation worker' were used this would make the harmonization of all uses of radiation a lot easier from a management point of view. The same name could be used regardless of the origin of the radiation.

Recommendations

4.2.1 The term "Atomic Radiation Worker" should be abandoned. The term "Radiation Worker" is more suitable than "Atomic Radiation Worker" since the former term can equally well be used by all occupationally-exposed workers, regardless of the source or regulatory jurisdiction of ionizing radiation. The designation of radiation workers should be based upon the areas in which they work and the likelihood of exposure.

4.2.2 Workplaces where radiation is used should be classified as "controlled" or "supervised" areas. These areas should be established so that it would be highly improbable for anyone working outside a controlled or supervised area to receive a radiation dose in excess of the dose limit (1 mSv per year on average) for a member of the public, in keeping with the ICRP recommendations.

Persons who are occupationally exposed to ionizing radiation will henceforth be referred to as radiation workers in this document.

4.3 ISSUE #3: *Dose Limits, Constraints and Administrative Levels*

Background

The dose limit recommended by the ICRP has been reduced from 50 mSv per year to an average effective dose of 20 mSv per year for workers and from 5 to an average of 1 mSv per year for members of the public (IC91).

In its 1990 recommendations (IC91), the ICRP stressed that the revised occupational dose limits were considered to be the dose level at which regular, deliberate, occupational exposure can reasonably be regarded as only just tolerable. Equal emphasis was placed upon the principle of optimization of protection, an important feature of which was the use of dose constraints. In most situations, a high proportion of operations can be conducted in such a way that the standard of protection is set by the process of constrained optimization and not by the regulatory dose limits. The dose constraint is a fraction of the occupational dose limit, but may be above the public dose limit. It is important to note that even though dose constraints may be set by the regulatory body after appropriate consultation with a facility (or class of facilities) or operator, these regulatory constraints are different from the prescriptive regulatory limits.

Discussion

Since it is usually possible to assess the level of individual occupational doses incurred in a well-managed radiation protection program, it then becomes feasible to establish a dose constraint for a given facility (or class of facilities) or operator.

Regulatory dose constraints should be supplemented by the establishment of recommended investigation levels for a given facility (or class of facilities) or operator. Exceeding an investigation level would require the facility or

operator to implement actions (e.g., amelioration of circumstances or conditions which resulted in unplanned exposure) to redress any weaknesses in radiation protection. Finally, a given facility (or operator) may establish its own reference values (or action levels) at a values lower than the investigation levels set by the regulatory body. These reference values (or action levels) include recording levels, above which a result should be recorded, lower values being ignored; investigation levels, above which the cause or implications of the result should be examined; and intervention levels, above which some remedial action should be considered.

In Canada, some occupationally-exposed workers who are not designated as ARWs but who receive doses slightly above 1 mSv per year are concerned that the change in the dose limits may change their classification from a member of the public (5 mSv dose limit under the old regulations) to an Atomic Radiation Worker (20 mSv annual dose limit proposed). In order to alleviate these concerns, these persons should be subject to an enforceable reference level or dose constraint (IC92) of 5 mSv per year and strict adherence to the ALARA process. The licensed facility or operator should undertake an appropriate investigation and subsequent corrective actions if the 5 mSv level is exceeded.

Recommendation

4.3.1 Appropriate regulatory bodies should give consideration to recommending a system of occupational- and source- related dose constraints. This would be in addition to the ALARA (optimization) process.

4.4 ISSUE #4: *Management and Organizational Structure*

Background

A protection and safety culture should pervade all organizations where workers are exposed to occupational hazards. Senior management is responsible for promoting safety culture by establishing the necessary framework and infrastructure; and by encouraging all personnel within the organization to adopt a personal commitment to safety principles and practices, which includes such elements as attitude, responsibility, competence and accountability (IA91b).

The management framework established by senior management should include a sound radiation safety program that is a balanced and integral part of the overall corporate safety program. Regardless of the nature or type of organization, it is the senior management that is responsible for ensuring that its radiation safety program meets the corporate needs of an organization as well as applicable regulatory requirements. On a day to day basis, this responsibility is delegated through line management to managers and to first-line supervisory staff. A detailed discussion of management's responsibilities and organization structure is presented in Appendix III. Additional guidance on this topic will be published by the ACRP in the near future (see ACRP-16, "Institutional Factors in Radiation Protection", in preparation).

Management Structure

The management structure of an organization will vary from one organization to another, depending upon its nature, complexity and size. However, all organizations with established radiation safety programs should ideally be structured in keeping with the following organizational model. Smaller organizations may be somewhat different and will likely combine the roles of some of the positions described below. Conversely, in large complex facilities or institutions, there may be a need for additional specialized positions, such as a health physics group for provision of radiation protection services on a corporate-wide basis.

The manager is responsible for directing and managing resources to ensure that corporate production functions are performed in full compliance with the corporate commitment to conventional and radiological safety policies and regulatory requirements, as embodied within the organization's safety culture.

The work supervisor is responsible for day-to-day production and supervision of work within the areas where radiation sources are in use. It is the direct responsibility (delegated from senior line management) of the work supervisor to ensure that sound conventional and radiation safety practices are implemented during work.

The radiation worker is responsible for undertaking production work, under the supervision of management, in areas where radiation sources are or may be in use, within the safety culture framework established by the organization. Radiation workers also have a personal responsibility to protect themselves, their colleagues and other people in the surrounding environment by demonstrating competence, responsibility and accountability.

The radiation protection officer (RPO)[3] (or radiation safety officer (RSO) in hospitals and universities) is usually responsible for the day-to-day administration of a radioisotope licence and for coordinating all aspects of radiation safety (including those associated with x-ray machines) in institutions such as health care facilities or in universities. Ideally, the RPO should not be a member of the operating management staff and should have no line responsibilities for production functions, since these could potentially result in conflicting priorities and impose constraints on some aspects of the radiation safety program. However, the RPO should cooperate with line management. For hospitals, AECB has provided some guidance (AE89).

The Health and Safety Committee (and the Radiation Safety Committee in larger organizations) independently monitors the implementation of management's radiation safety program and provides advice (or relays safety concerns) to the radiation protection officer and to line management on general or specific aspects (including adequacy of resources, training etc.) of conventional and radiological safety policies and work practices.

---

[3] RPO: Radiation Protection Officer (generic term for various radiation protection professionals, including a station health physicist, a radiation control supervisor, a radiation safety officer, etc.)

Worker Education

Workers who are occupationally exposed to radiological hazards need appropriate education to perform radiation work and it is the responsibility of management to ensure that such worker education is carried out. Management should regard training as an ongoing commitment and should make provision for educating workers at appropriate intervals. Specific radiation safety programs should be available for various categories of workers. This can be facilitated by drawing up training programs and subjecting them to regular reviews. For some cases, it may be appropriate to require employees to demonstrate successful completion of formal courses by written examinations or skills testing. For staff not directly employed in the use of radiation, the ability to recognize radiation warning symbols may be all that needs to be covered in an orientation period. Conversely, staff employed to manipulate high activity open sources may need weeks of didactic and practical training. Senior management should at least have a minimal knowledge in this area even if their work is not directly involved in radiation.

As part of the radiation safety education program, the RPO should identify the courses appropriate to staff, and the required period between refresher courses. An important part of the training is to ensure that staff have sufficient up-to-date knowledge for their job. The didactic training should be constantly referenced to detailed local policies and procedures. Some information (taken from AC90) relevant to the aims of worker training is presented in Appendix IV.

ALARA

For more than 30 years, radiation protection organizations have recommended that, in addition to regulatory dose limits, the process of "as low as practicable" (ALAP) and "as low as reasonably achievable" (ALARA) should be applied to all occupational exposures. The decision as to what is reasonable, economic and social factors being taken into account, has generally been left to the judgement and insight of licensees. The ICRP has offered advice on optimization and decision-making in radiological protection (IC83, IC89) and the AECB Advisory Committees have also provided advice on the application of the ALARA process in the regulation of nuclear activities (AC91b). However, the majority of persons using the National Dosimetry Service work with x-ray sources and formal ALARA analyses may be difficult in this domain. A small group of workers in medicine and dentistry, accounting for about 1 percent of all potentially exposed workers and 5 per cent of measurably exposed workers in these areas, contribute about 40 per cent to the total collective dose for this sector in the US and this also appears to be the case in Canada. Optimization processes should therefore concentrate on the most exposed workers (NC90).

Documentation of Procedures

Written procedures should be available for workers who are occupationally exposed to radiological hazards. These should be reviewed on a regular basis by the safety committee. A comprehensive Radiation Safety Manual prepared by the radiation safety personnel and approved by management is an integral part of the safety program and must be available as a reference to all workers within controlled and supervised areas.

Discussion

The first, and in many ways the most important, of the practical steps in implementing the recommendations of the ICRP and the IAEA is the establishment of a safety-based attitude in everyone concerned with all the operations from design to decommissioning. The aim of radiation protection should be combined with the aim of safety culture, which seeks to place a strong emphasis on the integration of safety issues at all levels of management and workers (IA91b). Awareness of the principles required for radiation protection should include awareness of other occupational hazards. Active collaboration with labour-management committees dealing with health and safety in all areas including that of radiation protection can function effectively to achieve this goal. The ACRP therefore wishes to emphasize its view to treat ionizing radiation with care rather than fear and that radiation risks be kept in perspective in the context of other occupational risks. These goals can only be achieved by a substantial commitment to training, and a recognition that safety is a personal responsibility and is of major concern to the top management. Close links between the management and the representatives of the workforce have a major role to play (IC91, IA91b).

Monitoring should be used to ascertain the ongoing extent of individual occupational exposure and provide justification for the maintenance or modification of radiological protection programs and the promotion of good methods of work.

The workplace procedures, including documented radiation protection procedures should be made available to control all occupational hazards to ensure that radiation remains a balanced component of the spectrum of risks to which workers are exposed.

Several publications set out typical requirements for worker education courses. The NCRP has addressed the topic in NCRP Report 71 (NC83). The AECB has recently released a Consultative Document C-121 titled "Requirements for a Radiation Safety Program for Consolidated Radioisotope Licences" (AE92) which contains some information on training requirements. In addition, the AECB has prepared a Consultative Document C-111 titled "Informing Workers on Radiation Risks Associated with their Work".

At the moment the AECB does not have a policy on the approach that licensees should adopt to fulfil ALARA. As pointed out by the ICRP in publications 37 and 55 and the ACRP in AC-2 (AC91b), ALARA is most easily implemented at the design stage. It is much more difficult at the operational level because of the constraints already imposed by the plant, etc. However, for the purposes of the staff who will be newly classified as radiation workers, the practical suggestions in NCRP 107 (NC90) might be adopted. The strategy proposed is to track individual and collective doses and establish action or reference levels for individuals and groups. When these levels are exceeded the exposures are reviewed and appropriate action is taken. Several practical examples are given in NCRP 107.

Implementation of ALARA is largely the responsibility of the licensee since this is frequently a matter of improvements in the physical and administrative design of a facility as and when required for increased protection of the worker and of the general public (AC90, AC91b). However, achievement of ALARA on a day-to-day

basis continues to rely on the commitment of workers as well as management to the underlying concept and to its application through proper operational procedures and training. In this regard, an essential requirement is a sincere will on the part of the worker to acquire the necessary knowledge to protect his or her own health and that of others and to use the proper means of protection at the proper time. Forethought and attention to safe working procedures is essential (AC90).

Recommendations

4.4.1 Management of radiation protection and safety programs should conform to the general principles of ICRP 60. The management structure should be applicable to all uses of radiation.

4.4.2 Government agencies and senior management of licensed institutions should make a firm commitment to the safety culture aspects of the radiation safety program and should provide appropriate resources. One way in which this could be promoted by the AECB is by requiring licensees, through the licensing process, to prepare both a radiation safety policy which expresses the commitment of senior management to radiation safety, and a program to implement that policy.

4.4.3 Any organization where occupational radiological hazards exist should be required to have a formal program of education and updating on radiation protection for radiation workers and management. The objective of radiation training for workers should be to enable them to protect themselves, their colleagues and other people in the surrounding environment. Appropriate training should also be extended to other workers who have limited or peripheral contact with radiation sources in the workplace.

4.5 ISSUE #5: *Monitoring*

Background

The 1990 ICRP recommendations stressed the importance of properly identifying groups of workers for whom individual monitoring is required in order to optimize use of resources. Three major technical factors should influence this decision: the expected level of dose or intake in relation to the relevant limits, the likely variations in the doses and intakes, and the complexity of measurement and interpretation procedures comprising the monitoring program (IC91). In addition, a licensee's consideration of personal versus non-personal monitoring will have to balance cost savings against possible difficulty in use of "soft data" in potential future radiation worker compensation claims, and possible radiation worker concerns regarding the adequacy of occupational radiation monitoring techniques.

All radiation workers in controlled and supervised areas should normally be subject to individual monitoring. Exceptions may be allowed for radiation workers for whom a dose assessment clearly indicates that their doses will be consistently below the public dose limits. In general, where an assessment indicates that an internal uptake could result in dose which is a significant

fraction of the individual's total annual dose or dose constraint then individual monitoring for internal dose should be conducted in keeping with the regulatory requirements. Bioassay procedures to quantify internal radiation exposure should be used routinely only for those who work in locations designated as controlled areas where radioactive materials are in use and in which there are grounds for expecting significant uptakes (IC91).

It must be recognized that there are many uncertainties in equating foetal intakes with dose. Moreover, the data which will allow equating risk with dose are limited.

Radiation protection programs for monitoring and preventing intakes of radionuclides are required at AECB-licensed facilities. Routine contamination monitoring of worker's hands, feet and clothing is required, particularly before leaving a radiation work area as is monitoring of work surfaces using wipe tests and direct contamination surveys. These types of contamination monitoring techniques are standard in all licensed facilities but should be re-emphasized on a periodic basis and especially after a pregnancy is declared. With these precautions in place, there should be very little opportunity for internal contamination in most licensed operations (uranium mines and nuclear power stations being notable exceptions).

Hospitals and universities are required by AECB licence conditions to establish bioassay programs for monitoring workers handling iodine-125, iodine-131 and tritium. Nuclear power plants are required to establish routine bioassay programs for tritium, and uranium refineries are required to establish similar programs for uranium. The AECB regulatory document R-91 (AE90) provides no specific guidance regarding which radionuclides (and activity) are to be included in routine bioassay programs, and as a result most AECB health care facilities continue to perform bioassay for radioiodines and tritium. Some AECB licensees who employ radioisotope workers which handle other short- and medium-lived radionuclides have voiced some concern about future regulatory requirements governing additional bioassay program requirements.

Short-lived radionuclides present in nuclear facilities and particularly those used in medicine (such as technetium-99m, thallium-201, gallium-67, etc.) may present problems with respect to determining internal dose from ingested or inhaled activity since few scientific data are available on the incidence, biodistribution and magnitude of many of these internally deposited radionuclides. This is especially the case for technetium-99m which is used in nuclear medicine departments by workers in amounts exceeding billions of becquerels. Although there is no evidence to suggest that such workers are significantly exposed, the AECB is currently funding a research project to study this matter. The issues surrounding accurate determination of internal dose (and whether such doses are even significant) for workers handling short-lived radionuclides in educational, research and medical institutions deserve further research.

Discussion

It would seem logical to rationalize the use of personal monitoring in all institutions where workers are occupationally exposed to radiological hazards,

regardless of whether they fall under federal or provincial jurisdiction. This would require "harmonization" of federal and provincial requirements and guidelines with respect to personal and non-personal monitoring.

Certain AECB licensees such as nuclear power utilities and AECL Research facilities have adopted the practice of monitoring essentially all staff. Consequently, regardless of any change in regulatory requirements or dose limits, there can be no additional persons to monitor. The situation is quite different in health care institutions, where many workers who have ancillary contact with radiation sources (particularly sources in nuclear medicine patients) are not required to be monitored. This practice has largely resulted from the expectation that very few workers would receive measurable doses and that no workers would receive doses above the existing 5 mSv public dose limit. Other considerations were the administrative difficulties and costs associated with issuing dosimeters to many more thousands of workers.

Under the proposed new dose limits, many additional workers in radiology, nuclear medicine and research within hospitals may have to be monitored. Certain hospital personnel providing nursing care for brachytherapy patients may also wish to be monitored, since about 20% of these personnel are likely to receive more than 1 mSv per year (Da89). On the other hand, some health care workers are currently being monitored without apparent justification. For example, the National Dose Registry statistics for 1990 show that there were over 20,000 health care workers (occupationally exposed to x-rays) who were issued TLD badges and who received no detectable radiation dose (As93).

An unknown number of ancillary workers including some nurses and porters, who might be unknowingly exposed by portable x-ray machines or who work where there is a large flow of nuclear medicine patients may have to be monitored on a trial basis at least to establish what level of radiation exposure they actually receive. Their doses would certainly be less than the current 5 mSv dose limit for members of the public, but may exceed the proposed 1 mSv limit.

Because of the emphasis on aggregate dose from external and internal sources in the new 1991 General Amendments (AE91a) to the AEC Regulations (an emphasis which dates from ICRP-26 in 1977), increased attention to internal sources of radiation will be necessary in many facilities using radioactive materials. Routine monitoring for internal contamination should be carried out for workers employed in controlled areas, for whom there is the possibility of significant intakes. Monitoring for internal contamination in workers who work only in supervised areas should not normally be necessary unless there are specific grounds for suspecting that intakes may have occurred, such as a transfer of contamination from a controlled area.

In general, where an assessment indicates that an internal uptake could result in dose which is a significant fraction of the individual's total annual dose then individual monitoring for internal dose should be conducted.

The majority of radioisotope licensees in Canada are relatively small and do not have the expertise to develop bioassay protocols. The AECB should provide guidance for licensees as to when bioassay is warranted (perhaps based on the amount of activity handled or types of procedures performed), acceptable standardized methods for performing bioassay measurements, recommended frequency of bioassay

measurements and how to calculate effective dose from any detected internal contamination.

Recommendations

4.5.1 All workers who are occupationally exposed to external radiation in controlled and supervised areas should normally be subject to individual monitoring. Exceptions may be allowed for radiation workers for whom a dose assessment clearly indicates that their doses will be consistently below the public dose limits. However, where such exceptions are made, area monitoring should be done to provide assurance that these conditions continue to be met.

4.5.2 Routine monitoring for internal contamination should be carried out for workers employed in controlled areas, for whom there is the possibility of intakes resulting in doses which are a significant fraction of a worker's occupational dose limit. Monitoring for internal contamination in workers who work only in supervised areas should not normally be necessary unless there are specific grounds for suspecting that intakes may have occurred.

4.5.3 The AECB should take the lead in developing and publishing standardized methods to detect and quantify internal contamination in workers and calculate the effective doses arising therefrom. This is particularly important in nuclear medicine, where methods for measuring internal contamination and for estimating annual intake of activity of some of the short-lived radiopharmaceuticals do not currently exist.

4.5.4 The AECB should ensure that licensees report occupational doses from external and internal radiation sources to the National Dose Registry, and that appropriate quality assurance requirements are established for institutions providing dosimetry services.

4.5.5 Provincial authorities should ensure that x-ray exposures are reported to the National Dose Registry and that appropriate quality assurance requirements are established for institutions providing dosimetry services.

4.6 ISSUE #6: *Pregnant Workers*

Background

A pregnant woman who is aware of her pregnancy before she is hired as an atomic radiation worker is required under current AEC Regulations to inform her employer, on being hired, that she is pregnant. Similarly, a woman who becomes pregnant after she is hired as an atomic radiation worker is required to inform her employer of her pregnancy as soon as she becomes aware of it. Under current dose limits, the pregnant atomic radiation worker can continue to perform normal duties if her exposure is less than 10 mSv or 0.6 mSv/2 weeks.

When pregnancy is declared, an assessment of the worker's recent radiation dose history and work assignments should be undertaken with the goal of minimizing occupational radiation exposure for the remainder of the pregnancy. In many of the larger nuclear facilities, it may be possible to transfer or re-assign the worker to an area of low or no occupational radiation exposure for the remainder of the pregnancy.

It should be noted that ICRP-60 implies a considerable change in thinking in respect of the protection of the foetus. The ICRP now recommends that the standard of protection for any conceptus be broadly comparable with that provided for members of the general public. Under this system of protection, the Commission recommends no special occupational dose limit for women in general.

Discussion

The AECB's proposed pregnancy dose limit of 2 mSv external radiation to the abdomen will have a significant impact on both workers and their employers, especially in the disciplines of nuclear medicine and radiotherapy, where the majority of technologists are females of childbearing age. The additional proposed pregnancy dose limit on internal radiation exposure to 0.05 ALI may further complicate the situation in many nuclear facilities, including nuclear medicine departments. Given the current state of knowledge, it will be almost impossible to effectively demonstrate compliance with the 0.05 ALI restriction during pregnancy. The limit of 0.05 ALI may also be unduly restrictive in uranium mines and mills where the ALI for some radionuclides, for example inhaled radon progeny and inhaled uranium dust, is derived primarily from radiation doses to the workers' lungs, and radiation doses to many other tissues including the foetus embryo may be very low. On the other hand, after maternal intake of radioiodine, the radiation dose to the foetal thyroid gland will depend upon the stage of gestation and the size of the uptake and could exceed the dose to the maternal thyroid gland.

It seems probable that adoption of the 0.05 ALI limit will result in many female ARWs being removed from radiation work for the remainder of the pregnancy and transferred or re-assigned to areas involving lower or no occupational radiation exposure. If that is not possible, these pregnant workers may be put on a paid or unpaid leave. The net predictable result will be increased radiation exposure for the remaining radiation workers or, if the worker is replaced, an increase in salary expenditures. This scenario of difficult and expensive choices will likely be replayed for many employers of female ARWs throughout the nuclear industry. The ACRP has previously recommended that the limit of 0.05 ALI should be postponed until the AECB has had time to estimate foetal doses from ALI's of various radionuclides and to evaluate methods of measuring 0.05 ALI over the period of pregnancy (AC91c).

The removal of women from radiation work during pregnancy does not involve any obvious discrimination and violation of human rights if the employer provides alternative work at the same pay. For most large facilities this will likely be both the policy and the practice, as is the case in nuclear power plants, nuclear fuel processing facilities and AECL research facilities. The problem arises with those who employ few specialized workers, who may not have the resources to provide alternative work and simultaneously hire a temporary replacement. For nuclear medicine and radiotherapy departments, there may also be a problem with availability of replacement workers.

One might also expect a reaction from the women's action groups who are opposed, from a human right's perspective, to discrimination on the basis of gender. It may be preferable to describe the stringent dose limit restrictions during pregnancy as foetal protection policy, (St87) but the reality is that removal from work for almost a year (pre- and postpartum leave) for every pregnancy will undoubtedly cause considerable difficulty and disruption for the employer and possible loss of income and/or career advancement for the worker.

In view of these concerns, the AECB has met with senior representatives of organizations such as the Canadian Nurses Association, the Canadian Association of Medical Radiation Technologists, and the Canadian Organization of Medical Physicists. Since no solutions to the concerns were suggested, the AECB held meetings across the country with female radiation workers, targeting nuclear medicine technologists and other medical workers. Most of these workers felt that the ICRP's recommendations were too restrictive and were not justified by the risks (My93). If implemented, these would result in lay-offs and eventual reluctance of employers to hire women in the nuclear medicine field. Workers were also of the opinion that demonstrating compliance would be impossible and recommended two options: either a compromise limit of 4-5 mSv, or remaining with the current limit of 10 mSv over the duration of the pregnancy. As a result of these consultations, AECB staff are currently developing a new proposal on the dose limit for pregnant ARWs which will be included when the revised C-122 proposals are published in Part 1 of the *Canada Gazette*.

The 1991 AECB General Amendments (AE91a) clearly indicate that the pregnancy dose limit of 10 mSv applies to dose received by the foetus. At this point in time (1993), there is some animal data and very little human data on foetal radiation dose due to the uptake, retention and distribution of radionuclides due to internal contamination of the mother. The AECB published a literature review on this topic, authored by E. Lamothe (AE89a), which concluded that "*Biological distribution data as a function of gestational age (in animal models and from human data, where available) should be acquired for many of the radionuclides ... and possibly some radiopharmaceuticals. This data would allow for a better understanding of the risk for occupationally exposed individuals*". The ACRP agrees that more research in this area is clearly required, so that foetal radiation doses from maternal intakes can be calculated in accordance with the requirements of the proposed general amendments.

For those pregnant radiation workers exposed to possible internal contamination from open source radionuclides, it would be very useful if the AECB established "Pregnancy Limits on Intake" or PLI, similar to the Annual Limit on Intake or ALI (IC91a). The PLI would be derived from the pregnancy (foetal) dose limit, and the known or estimated dose (mSv per MBq) to the foetus from maternal intake. These values would be very useful for licensees in the assessment of working conditions for pregnant workers.

The ACRP suggests that new AEC regulations include a statement to the effect that neither the AECB nor the licensee have the authority to require that information on pregnancy be provided by the worker. Such a requirement could be considered to be discriminatory and an invasion of personal privacy. It is the fundamental responsibility of the pregnant worker to decide when or whether she will formally declare her condition to her employer. The ACRP recommends that the AECB should formally recognize this concept. The ACRP supports voluntary (not mandatory)

disclosure to the employer since this will encourage both parties to establish a mutual goal of optimizing the worker's radiation dose and enabling her to work during her pregnancy if she chooses.

There are also good reasons, which were previously noted by the ACRP (AC91c), for not requiring any special dose limits for pregnant workers, and particularly for NOT requiring mandatory declaration of pregnancy by a pregnant female radiation worker. This option, which also appears to be reasonable, would permit the informed pregnant worker to make her own decision concerning the limits on potential radiation hazards to which she might choose to expose her own child in the womb. If this alternative option were to be adopted, education of radiation workers concerning radiation risks including those related to pregnancy should be emphasized. Some of the published documents from which information risks related to pregnancy could be derived include IC91, AC91a, AE92b and My93. Application of ALARA should be especially emphasized in the case of pregnant workers (AC91c).

Recommendations

4.6.1 All female radiation workers should be educated in respect of the potential effects of radiation on the foetus and be provided with written information.

4.6.2 For the reasons outlined in BMD 91-210 (AC91a), the AECB should consider one of two alternatives for pregnancy dose limits: a) Retain the pregnancy dose limits on radiation dose to the embryo or foetus that are given in the proposed 1991 General Amendments (AE91a) until such time as AECB is certain that it can overcome serious practical difficulties in demonstrating compliance with any more restrictive dose limits; or b) Alternatively, AECB could omit any special restrictions on dose limits to pregnant workers in their new regulations and insist rather on application of the ALARA principle and permit informed workers to make their own individual choice concerning radiation exposures during pregnancy.

4.6.3 The AECB should support research into the determination of embryonic/foetal radiation doses due to the maternal intake of radionuclides during pregnancy.

APPENDIX I

CURRENT REGULATIONS GOVERNING OCCUPATIONALLY EXPOSED PERSONNEL IN OTHER COUNTRIES

I.1 European Economic Community (EEC) Countries

Regulations currently in place in most EEC countries conform more or less to the principles of ICRP 26 published in 1977, and are based on Euratom Directives 80/836 (15 July 1980) and 84/467 (3 September 1984) which embody the ICRP 26 recommendations. As these directives are enacted into law in the various countries slight modifications occur in the actual implementation. No distinction is made between workers exposed to radiation from radioactive materials and those exposed to radiation from x-ray machines.

I.2 United Kingdom (UK)

In the UK it is the responsibility of National Radiological Protection Board (NRPB) to advise government on radiation protection, including the implementation of the ICRP recommendations. Regulations currently in place in the UK conform closely to ICRP 26. Management responsibilities are detailed in the Regulations (IR85). These include appointment of Radiation Protection Advisors (RPAs) and Radiation Protection Supervisors (RPSs). Controlled and Supervised areas corresponding to 0.3 (15 mSv per year) and 0.1 (5 mSv per year) of the current 50 mSv annual occupational dose limit are defined and posted with radiation warning signs accordingly. Written procedures (Local Rules) are enforced for all radiation areas.

Classified Radiation Workers are defined as those workers who are likely to receive a radiation dose in excess of 0.3 of the dose limit (in excess of 15 mSv annually).

I.3 France

Radiation Protection regulations are the legal implementation of the Euratom Directives. The two volume 613-page "Protection contre les rayonnements ionisants" (Fr90) covers all aspects of the use of radiation, including isotopes, nuclear power and radiation emitting devices. Controlled and Supervised Areas are strictly enforced and posted with warning signs.

Workers are classified as Category A if they could receive more than 0.3 (15 mSv) of the current 50 mSv annual dose limit and Category B if they could receive more than 0.1 (5 mSv). Medical examinations appropriate to the activity are required for Category A workers every 6 months. A medical file is kept on each worker by the occupational health physician and each worker has an identity card specifying medical surveillance dates and restrictions.

I.4 Germany

There are two Ordinances which cover Protection against Damage Caused by Ionizing Radiation (Gr89) and an x-ray Ordinance which deals separately with x-ray

protection. Details are given of the appointment of appropriate Radiation Protection Officers, the designation of Controlled and Supervised Areas, and training for those that enter these restricted areas. Occupationally Exposed Persons are classified as Category A or B as recommended in ICRP 26. Medical examination is mandatory every year for Category A workers, i.e. those likely to receive doses in excess of 15 mSv per year.

I.5 United States (USA)

The Nuclear Regulatory Commission (NRC) either directly or through arrangements with "agreement states" controls the use of radioactive substances in the USA. The latest version of the NRC 10 CFR Part 20 et al. titled "Standards for Protection Against Radiation" was published 21 May 1991, and will be implemented in 1993. All the ICRP recommendations are incorporated except those in ICRP 60 and subsequent publications. This means that the annual dose to the general public is limited to 1 mSv and the annual dose limit for occupational exposure is 50 mSv. There is no special name for radiation workers. A firm requirement for issuance of an institutional radioisotope licences is a written radiation safety program appropriate to the size of operation. An extensive discussion of comments received during the formation of the NRC regulations is given along with an comprehensive glossary. All the above regulations come with extensive guidance notes and commentary. It should be noted however, that individual states have regulatory authority over the use of x-ray machines, leading to the same multi-jurisdictional situation and problems (particularly in health care facilities) that occur in Canada.

APPENDIX II

MEDICAL SURVEILLANCE OF RADIATION WORKERS IN CANADA

An important purpose of medical surveillance is to ensure that the worker is fit both physically and psychologically to undertake the tasks which he or she may be called upon to perform within the requirements of a specific job description. The AEC Regulations (AE88, AE91a) require that every atomic radiation worker must undergo a medical examination of such nature, extent and frequency as may be specified in any licence affecting the persons. The nature, extent and frequency of these examinations will normally be those recommended by the medical advisers appointed by the AECB under the AEC Regulations. In actual fact, very few AECB licences currently require medical examination of employees. The only licensees that are required by the AEC Regulations to conduct medical surveillance of workers are those involved in uranium mining operations. None of the other licences examined to date, apart from uranium mining operations, actually specify any need for medical surveillance of employees (Go92). The fact that nearly all licensees do in fact currently have some program for medical surveillance of employees in place is thus attributable to the desire of employers and employee representatives to ensure the health of employees, as well as to some provincial legislation governing the health of workers, but it is not due directly to the AEC Regulations or the AECB licensing procedures.

Guidelines for the medical surveillance of radiation workers were first published in 1991 by the AECB's Group of Medical Advisers (GM91) and were subsequently revised in 1993 (GM93a). Although these guidelines emphasize radiation-related procedures, they stress that other important procedures related to non-radiation hazards are an essential part of effective medical surveillance of radiation workers. It is further noted that there are few specific diseases which render a worker unfit to be a radiation worker. The medical conditions which a physician must look for are those which would impair the ability to wear protective clothing and respirators, the ability to hear alarms and to assess radiation hazards and the ability to work with specific tools and equipment. These guidelines also clearly state that medical examinations for radiation workers need be no different than for other workers performing similar tasks in the absence of radiation and that some degree of impairment may often be compatible with the requirements of a specific job (GM93a).

The AECB Medical Adviser is given broad powers to enter the premises of a licensee in order to inspect and copy all relevant radiation dose records, and to observe working conditions (AE88, AE91a). In cases of overexposure where a radiation worker receives a dose in excess of the regulatory dose limit, the Medical Adviser may prescribe "special assessments and tests" (GM93a). For example, chromosome analysis and daily serial blood counts may be prescribed to confirm the calculated whole body dose or to provide grounds for its re-assessment, and will have a bearing on the clinical management an overexposed individual (GM93b). A Medical Adviser may also recommend that consideration be given to any psychological trauma resulting from the overexposure. "In some cases, extended psychological support and counselling may be required for both the overexposed individual and his immediate family" (GM93b).

In general, medical examinations of an individual will not be able to detect any short-term physiological effects of exposure to low levels of radiation. The dose limits recommended by the ICRP are intended to prevent any occurrence of short-term effects and to minimize the occurrence of long-term stochastic effects such as induction of cancer (IC77, IC91). These potential long-term consequences can only be detected, if at all, by epidemiological studies of large groups of workers, such as are being carried out by a wide variety of agencies in many countries (UN88, IC91). The dose limits recommended by the ICRP (IC91) and the AECB Group of Medical Advisers (GM92) of 500 mSv or 5000 mSv to the skin in the event of a nuclear emergency are in fact intended to prevent any occurrence of permanent short-term effects such as permanent sterility, skin damage, physiological damage to other tissues, etc.

APPENDIX III

MANAGEMENT STRUCTURE AND RESPONSIBILITIES
(adapted from IA91a, IA91b, IA94)

The responsibilities of senior management include:

- the establishment of occupational radiation protection policies, procedures and organizational arrangements for implementing the corporate and regulatory requirements of a radiation safety program;

- the designation of key personnel (such as the radiation protection officer); the delegation of sufficient authority, with access to senior management levels; and the establishment of clear lines of responsibility;

- the provision of suitable and adequate radiation protection facilities, equipment and services, the extent of which depends on the nature and magnitude of the radiation risks;

- the provision of all necessary technical, health and medical services needed;

- the provision of appropriate protective and monitoring equipment and training to ensure its proper use;

- the provision of suitable and adequate manpower and appropriate training. This includes radiation protection training, to ensure that workers are made aware of the risks of radiation. It also includes periodic retraining and updating in order to ensure the necessary level of competence;

- the maintenance of adequate records as required by regulatory agencies;

- the undertaking of an objective peer review of the adequacy and effectiveness of its radiation safety program on a regular basis; and

- reporting incidents and undertaking appropriate investigations, corrective actions and feedback mechanisms to help prevent future incidents.

The management structure of an organization will vary from one organization to another, depending upon its nature, complexity and size. However, all organizations with established radiation safety programs should ideally be structured in keeping with the following organizational model. Smaller organizations may be somewhat different and will likely combine the roles of some of the positions described below. Conversely, in large complex facilities or institutions, there may be a need for additional specialized positions.

The manager is responsible for directing and managing resources to ensure that corporate production functions are performed in full compliance with the corporate commitment to conventional and radiological safety policies and regulatory requirements, as embodied within the organization's safety culture. Within the Canadian context, this position may correspond to the manager of a nuclear medicine department in a large hospital; the production manager in a nuclear

power station; or the production manager in an uranium mine. With respect to radiation safety, the manager has the responsibility for ensuring that sufficient resources (see above) are allocated for implementing an adequate and effective radiation safety program. This is normally undertaken after appropriate consultation with the radiation protection officer; work supervisors; the Health and Safety Committee; the Radiation Safety Committee (in larger organizations); and senior management.

The **work supervisor** is responsible for day-to-day production and supervision of work within the areas where radiation sources are in use. Within the Canadian context, the work supervisor would correspond to a laboratory supervisor in a large hospital; a foreman in a nuclear power plant; or a researcher in a large university. In some instances, it could correspond with the "responsible user" identified in a radioisotope licence. It is the direct responsibility (delegated from senior line management) of the work supervisor to ensure that sound conventional and radiation safety practices are implemented during work. The work supervisor need not be an expert in radiation protection, but must have received sufficient training to ensure the safety of the work environment and the workers. It is critical that this person respects the authority of the radiation protection officer to stop or modify work due to unsafe radiological practices or work environments.

The **radiation worker** is responsible for undertaking production work, under the supervision of management, in areas where radiation sources are or may be in use, within the safety culture framework established by the organization. Although management has a primary responsibility for ensuring the conventional and radiation safety of the worker and the work environment (through provision of adequate resources, equipment, training, etc.), radiation workers also have a personal responsibility to protect themselves, their colleagues and other people in the surrounding environment by demonstrating competence, responsibility and accountability. In certain large complex facilities such as nuclear power plants, radiation workers can be sufficiently qualified in radiation protection to independently assess radiological hazards; select their own protective equipment and dosimetry; and assume responsibility for the radiological protection of other workers.

The **radiation protection officer (RPO)** (or **radiation safety officer (RSO)** in hospitals and universities) is usually responsible for the day-to-day administration of a radioisotope licence and for coordinating all aspects of radiation safety (possibly including those associated with x-ray machines) in institutions such as health care facilities or in universities. In facilities such as nuclear power plants, uranium refineries and large nuclear research establishments, the RPO may be responsible for the broader administration of a radiation safety program. The RPO should have university training or equivalent standing, and considerable practical expertise in radiation protection. Within the Canadian context, the radiation protection officer would correspond to a radiation safety officer at a hospital or university; a senior health physicist at an uranium refinery. Ideally, the RPO should not be a member of the operating management staff and should have no line responsibilities for production functions, since these could potentially result in conflicting priorities and impose constraints on some aspects of the radiation safety program. However, in certain types of institutions or in smaller facilities, this arrangement may not be feasible. Regardless of the specific arrangement, the RPO should have

sufficient authority and resources to function effectively and should have access to senior management. Finally, the RPO should be a member of the organization's Health and Safety Committee (and the Radiation Safety Committee in larger organizations, where appropriate).

The Health and Safety Committee (and the Radiation Safety Committee in larger organizations) independently monitors the implementation of management's radiation safety program and provides advice (or relaying safety concerns) to the radiation protection officer and to line management on general or specific aspects (including adequacy of resources, training etc.) of conventional and/or radiological safety policies and work practices. These committees should have sufficient resources to function effectively, and should have access to senior management if radiation safety concerns cannot be satisfactorily resolved at the level of work supervisors.

APPENDIX IV

EDUCATIONAL OBJECTIVES FOR RADIATION WORKERS

Protection against radiation, like protection against any other risks in the working place or to the surrounding environment, is only achievable with the full participation of the worker. The objective of radiation workers should be to protect themselves, their colleagues and other people in the surrounding environment against potential harm from unnecessary radiation exposure (AC90).

To achieve these objectives, the radiation worker would require some knowledge of:

(i) basic principles of radiation protection;

(ii) applicable conditions of the licence and federal and provincial radiation protection Regulations;

(iii) equipment for monitoring radiation levels;

(iv) the working environment and its radiological hazards;

(v) protective equipment such as respirators, gloves, and other means of protection such as ventilation, shielding materials and waste disposal requirements; and

(vi) emergency programs of the facility.

REFERENCES

AC90 ACRP-11. Basic Principles of Radiation Protection in Canada. Advisory Committee on Radiological Protection. AECB INFO-0340 (1990).

AC91a ACRP-13. A Review of Radiation Risk Estimates. Advisory Committee on Radiological Protection. AECB INFO-0389 (1991).

AC91b AC-2. Application of the ALARA Process in the Regulation of Nuclear Activities. Advisory Committee on Radiological Protection/Advisory Committee on Nuclear Safety. AECB INFO-0387 (1991).

AC91c ACRP letter to Dr. R.J.A. Lévesque, including comments on AECB Regulatory Guide C-122. Submitted as BMD 91-210 (1991).

AE83 AECB Regulatory Guide: Bioassay Requirements for ^{125}I and ^{131}I in Medical, Teaching and Research Institutions. AECB Regulatory Document R-58 (September 1983).

AE84 Change in Radioisotope Licences Issued For Use of Radioactive Material in Medicine. AECB Notice 84-6 (October 1984).

AE87 Notice to Cancer Clinics Regarding a Change in AECB Policy With Respect to Radioactive Implants at Other Institutions. AECB Notice 87-2 (February 1987).

AE88 Atomic Energy Control Regulations with Amendments to February 25, 1988. Office consolidation. Atomic Energy Control Board (1988).

AE89 Notice To All Hospitals and Nuclear Medicine Clinics Re: Radiation Safety Officer (RSO). AECB Notice 89-3 (March 1989).

AE89a Literature Review of the Studies on Uptake, Retention and Distribution of Radionuclides by the Foetus. E.S. Lamothe, Atomic Energy Control Board. AECB INFO-0332 (October 1989).

AE90 AECB Regulatory Policy Statement "Monitoring and Dose Recording for the Individual." AECB Regulatory Document R-91 (1990).

AE91a Proposed General Amendments to the Atomic Energy Control Regulations. Atomic Energy Control Board (November 1991).

AE91b AECB Consultative Document C-122. Proposed Amendments to the Atomic Energy Control Regulations for Reduced Radiation Dose Limits Based on the 1990 Recommendations of the International Commission on Radiological Protection, Atomic Energy Control Board (1991).

AE92 AECB Consultative Document C-121. Requirements for a Radiation Safety Programme for Consolidated Radioisotope Licences: A Proposed Regulatory Guide. (August, 1992).

AE92b Comments on ICRP-60 Rationale for Dose Limits for the Pregnant Worker. AECB Research Report No. 7-179-1 prepared by D.K. Myers. AECB INFO-0421 (1992).

As93 J.P. Ashmore and W.N. Sont. Annual Occupational Radiation Dose Statistics From The National Dose Registry - 1991. Personal communication (1993).

Ca91 H.M. Carisse, Cameco Compliance and Licensing Superintendent; personal communication (December 1991).

Ch84 S.H. Ching, K.P. Ho and H. Bayne. Gamma doses and radon daughter exposures in some Canadian uranium mines and implications with respect to the proposed regulatory amendments. Occupational Radiation Safety in Mining, Vol. 2, pp. 567-577, Canadian Nuclear Association (1984).

Da89 R. Datta and S. Datta. Nursing Personnel Taking Care of Brachytherapy Patients: To Be or Not To Be Classified as Radiation Workers. Health Physics, 57, pp. 199-201 (1989).

Fr90 Hygiène et Sécurité. Protection contre les rayonnements ionisants, France (1990).

GM91 GMA-1. Guidelines for the Medical Surveillance of Atomic Radiation Workers. Group of Medical Advisers, Atomic Energy Control Board, INFO-0402 (1991).

GM92 GMA-2. Guidelines on Radiation Exposure Levels For Emergency Situations. Group of Medical Advisers, Atomic Energy Control Board, INFO-0422 (1992).

GM93 GMA-6. Guidelines for Counselling After Occupational Overexposure to Ionizing Radiation. Group of Medical Advisers, Atomic Energy Control Board (1993).

GM93a GMA-8. Revised Guidelines for the Medical Surveillance of Radiation Workers. Group of Medical Advisers, Atomic Energy Control Board (1993).

Go92 J.P. Goyette, Atomic Energy Control Board, Personal communication (1992).

GR89 GRS. Protection against Damage Caused by Ionizing Radiation. GRS, Germany (1989).

Hu91 W. Huda, J. Bews, K. Gordon, J.B. Sutherland, W.N. Sont, J.P. Ashmore. Doses and Population Irradiation Factors for Canadian Radiation Technologists (1978 to 1988). Canadian Association of Radiologists Journal Vol. 42, No. 4 (August 1991).

IA91a IAEA Safety Series No. 1, Revision 1991. Safe Use of Ionizing Radiations in the Workplace. Final draft arising out of the Second Advisory Group Meeting. International Atomic Energy Agency, Vienna (May, 1991).

IA91b IAEA Safety Series No. 75, INSAG-4, Safety Culture. International Atomic Energy Agency, Vienna (1991).

IA94 IAEA, FAO, ILO, NEA, PAHO, WHO Joint Secretariat. Basic Safety Standards: International Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources. In press. (1994).

IC64 ICRP Publication 6. Radiation Protection Recommendations of the International Commission on Radiological Protection As Amended 1959 and Revised 1962 (1964).

IC66 ICRP Publication 9. Radiation Protection Recommendations of the International Commission on Radiological Protection Adopted September 17, 1965 (1966).

IC77 ICRP Publication 26. Recommendations of the International Commission on Radiological Protection. Annals of the ICRP 1977, Vol. 1, No. 3 (1977).

IC77a ICRP Publication 24. Radiation Protection in Uranium and Other Mines. Annals of the ICRP, Vol. 1, No. 1 (1977).

IC77b ICRP Publication 25. The Handling, Storage, Use and Disposal of Unsealed Radionuclides in Hospitals and Medical Research Establishments. Annals of the ICRP, Vol. 1, No. 2 (1977).

IC82 ICRP Publication 35. General Principles of Monitoring for Radiation Protection of Workers. Annals of the ICRP Vol. 9, No. 4 (1982).

IC83 ICRP Publication 37. Cost-benefit Analysis in the Optimization of Radiation Protection. Annals of the ICRP, Vol. 10, No. 2-3 (1983).

IC86 ICRP Publication 47. Radiation Protection of Workers in Mines. Annals of the ICRP, Vol. 16, No. 1 (1986).

IC88 ICRP Publication 54. Individual Monitoring for Intakes of Radionuclides by Workers: Design and Interpretation. Annals of the ICRP, Vol. 19, No. 1-3 (1988).

IC89 ICRP Publication 55. Optimization and Decision-making in Radiological Protection. Annals of the ICRP, Vol. 20, No. 1 (1989).

IC89a ICRP Publication 57. Radiological Protection of the Worker in Medicine and Dentistry. Annals of the ICRP Vol. 20, No. 3 (1989).

IC91 ICRP Publication 60. 1990 Recommendations of the International Commission on Radiological Protection. Annals of the ICRP Vol. 21, No. 1-3 (1991).

IC91a ICRP Publication 61. Annual Limits on Intake of Radionuclides by Workers Based on the 1990 Recommendations. Annals of the ICRP, Vol. 21, No. 4 (1991).

IR85a The Ionising Radiations Regulations 1985: Her Majesty's Stationery Office (1985).

IR85b Approved Code of Practice: The Protection of Persons Against Ionizing Radiation Arising From Any Work Activity; Her Majesty's Stationery Office (1985).

Li91 N.C. Lind, J.S. Nathwani and E. Siddall. Management of risk in the public interest. Can. J. Civ. Eng. 18, pp. 446-453 (1991).

My91 D.K. Myers, personal communication (1991).

My93 D.K. Myers and C. Pomroy, Meetings on Radiation Risks to the Foetus and *Radiation Dose Limits for Pregnant Workers*, Bulletin Canadian Radiation Protection Association, Vol. 14, No. 1, p. 8 (1993).

NC83 NCRP Report 71. Operational Radiation Safety - Training. National Council on Radiation Protection and Measurements, Bethesda, Md. (1983).

NC90 NCRP Report 107. Implementation of the Principle of ALARA for Medical and Dental Personnel. National Council on Radiation Protection and Measurements, Bethesda, Md. (1990).

Rh91 M. Rhéaume, personal communication (December 1991).

St87 J. Mager Stellman. Women's Health and the Law. Women and Health. Vol. 12(1), pp. 105-125 (1987).

UN88 UNSCEAR 1988 Report. Sources, Effects and Risks of Ionizing Radiation. Annex A: Exposures from Natural Sources of Radiation. United Nations, New York (1988).

US91 USNRC 10CFR Part 20 et al. Standards for Protection Against Radiation. US Nuclear Regulatory Commission (1991).

Ya91 A. Yassi, Medical Director, Department of Occupational and Environmental Medicine, Winnipeg Health Sciences Centre. Personal communication (1991).

GLOSSARY

ACRP: Advisory Committee on Radiological Protection, Atomic Energy Control Board of Canada

activity: the number of nuclear transformations of a radioactive nuclide per unit time; units: becquerel (Bq)

AECB: Atomic Energy Control Board of Canada

AECL: Atomic Energy of Canada Limited

ALARA: all exposures shall be kept As Low As Reasonably Achievable, economic and social factors being taken into account

ALI: annual limit on intake (see below)

annual limit on intake (ALI): the amount of radioactive substance taken into the body in one year that will result in a "committed dose" equal to either the stochastic or non-stochastic dose limit; different ALI values apply to "intake" by inhalation and ingestion, and different values apply to atomic radiation workers and members of the public

ARW: Atomic Radiation Worker

becquerel (Bq): a unit of activity equal to one radioactive disintegration per second

BRMD: Bureau of Radiation and Medical Devices, Health and Welfare Canada

CEA: Commissariat à l'énergie atomique (France)

collective dose: the sum of the individual radiation doses received by a group of person, expressed in person-sieverts

committed dose: the total dose received from a radioactive substance in the body during 50 years following the intake of this substance in the case of workers and 70 years following the intake in the case of children

deterministic effects: effects whose severity is frequently a function of dose and for which doses above some threshold dose is required; these effects were previously referred to as "non-stochastic effects"

detriment: the mathematical expectation of individual or collective harm incurred from exposure to radiation, taking into account the probability of each type of deleterious health effect and the severity of each effect

dose: a dose of radiation, either an "absorbed dose" or "equivalent dose", or "effective dose", depending on the context

dose commitment: the sum of all doses received following the release or intake of a given amount of a radioactive material, summed over a period of time extending to infinity

dose effect (dose-response) model: a mathematical formulation of the way the effect (or biological response) depends on dose

dose equivalent: replaced by "equivalent dose"

dose limit: a legal limit on radiation dose

EEC: European Economic Community

effective dose: the sum of the equivalent doses received by different tissues of the human body, each multiplied by the internationally recommended values of the "tissue weighting factors" assigned to each respective tissue; the "tissue weighting factor" reflects the probability that a unit dose of radiation to the tissue in question will result in a cancer in the exposed person or a serious genetic disorder in the descendants of the exposed person; the sum of the "tissue weighting factors" for all tissues of the body is 1.0; replaces "effective dose equivalent"

effective dose equivalent: replaced by "effective dose"

embryo: the developing organism from one week after conception to the end of the second month

equivalent dose: the "absorbed dose" multiplied by a "radiation weighting factor" to account for the different potential for injury of different types of radiation, where the "absorbed dose" is the amount of energy absorbed by the body, or in an organ or tissue of the body, due to exposure to ionizing radiation, divided by the respective mass of the body, organ or tissue; a gray of "absorbed dose" multiplied by the appropriate "radiation weighting factor" yields the "equivalent dose" in units of "sievert"; replaces "dose equivalent"

exposure: exposure to an internal or external source of radiation, or, depending on the context, the product of the concentration of a radioactive substance in air (or the dose rate from a source of radiation) and the duration of exposure to that concentration (or dose rate)

foetus: the developing child in the human uterus after the end of the second month

GMA: Group of Medical Advisers to the AECB, Atomic Energy Control Board of Canada

gray (Gy): the special name of the unit of "absorbed dose"; (1 Gy = 1 joule/kg)

IAEA: International Atomic Energy Agency

ICRP: International Commission on Radiological Protection

in utero: in the womb; i.e., before birth

ionizing radiation: radiation which is sufficiently energetic to dislodge electrons from an atom and thus to produce ions in an otherwise non-ionized medium

JWHSC: Joint Workplace Health and Safety Committee

latent period: the period of time between exposure and expression of the disease. After exposure to a dose of radiation, there is a delay in several years (the minimum latent period) before any radiation-induced cancers are seen

MBq: megabecquerels

mSv: millisieverts

NCRP: National Council on Radiation Protection and Measurements, USA

NM: Nuclear Medicine

NRC: Nuclear Regulatory Commission (USA)

NRPB: National Radiological Protection Board (UK)

nuclear facility: a nuclear reactor, a sub-critical nuclear reactor, a particle accelerator, a uranium or thorium mine or mill, a plant for the separation, processing, reprocessing or fabrication or fissionable substances, a plant for the production of deuterium or deuterium compounds, and a facility for the storage or disposal of prescribed substances, including all land, buildings and equipment that are connected or associated with such reactor, accelerator, plant or facility

occupational dose or occupational exposure: a radiation dose or an exposure to radiation received as a result of employment as a radiation worker

person-sievert (p-Sv): the unit of population exposure obtained by summing individual dose equivalent values for all people in the exposed population; the unit of "collective dose"

quality factor (Q): replaced by "radiation weighting factor"

radiation weighting factor: an LET-dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity (i.e. the "equivalent dose") which corresponds more closely to the degree of biological effect produced by x- or low-energy gamma rays; "absorbed dose" in Gy x "radiation weighting factor" = "equivalent dose" in Sv

radiogenic: caused by radiation

RPA: Radiation Protection Advisor

RPO: Radiation Protection Officer (generic term for various radiation protection professionals, including a station health physicist, radiation control supervisor, a radiation safety officer, etc.)

RSO: Radiation Safety Officer (the title of the radiation protection officer which is commonly used in hospitals and universities)

safety culture: that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, safety issues receive the attention warranted by their significance.

sievert (Sv): the special name of the unit of "equivalent dose" and of "effective dose"

$T_{1/2}$: radioactive half-life

tissue: group of similar cells which together perform certain specialized functions (e.g,, bone marrow, bone surfaces, and eye lenses)

tissue weighting factor: a factor by which the "equivalent dose" received by any organ or tissue of the body is multiplied to calculate an "effective dose" in order to account for the risk of fatal cancer or inheritable injury resulting from irradiation of that organ or tissue compared to the total risk of such stochastic effects resulting from the irradiation of the whole body

TLD: thermoluminescence dosimeter

UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation

WHMIS: Workplace Hazardous Materials Information System

WHO: World Health Organization

WLM: Working Level Month

x-ray: an electromagnetic radiation emitted during certain rearrangements of the electron shells of an atom; x-rays may be produced during radioactive decay or from the slowing down of fast electrons in any material; they are usually obtained from x-ray machines in which a metallic target is bombarded with fast electrons in a vacuum

ACKNOWLEDGEMENTS

Members of ACRP Working Group-7

K.L. Gordon (Chairman)
J.E. Aldrich
C. Bean
G. Dupras
D.K. Myers
M.R. Rhéaume
J.P. Goyette (Scientific Secretary)

The Committee is indebted to Drs. W. Sont and P. Ashmore (Bureau of Radiation and Medical Devices, Health and Welfare Canada), for providing a special breakdown of 1991 data (Table 2) in the National Dose Registry.

All the members of the Advisory Committee on Radiological Protection.