RAS 10983

Volume 28 No. 4 1998 ISSN 0146-6453

ICRP

Annals of the ICRP

PUBLICATION 81

Radiation Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste

Pergamon

6-5-00

Template = SECY-028

SECY-02

Annals of the ICRP

Published on behalf of the International Commission on Radiological Protection

Editor: J. VALENTIN, *ICRP, SE-171 16 Stockholm, Sweden*

Subscription Information

Annals of the ICRP is published as 1 volume of 4 issues per annum

Annual Institutional Subscription Rates 1998: Europe, The CIS and Japan, 429 Dutch Guilders. All other countries US$246. Associated Personal Subscription Rates are available on request for those whose institutions are library subscribers. Sterling prices exclude VAT. Non-VAT registered customers in the European Community will be charged the appropriate VAT in addition to the price listed. Prices include postage and insurance and are subject to change without notice. (Each report will be published as soon as material is received from the ICRP, so that issues will not necessarily appear at regular intervals.)

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This journal is indexed/abstracted in: App. Health Phy. Abstr., Biosis Data., CABS and SSSA/CISA/ECA/ISMEC.

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Periodicals postage paid at Rahway, New Jersey. *Annals of the ICRP* (ISSN 0146-6453) is published four times a year, in March, June, September and December, in one volume, by Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK. The annual subscription in the USA is $246. *Annals of the ICRP* is distributed by Mercury Airfreight International Ltd, 365 Blair Road, Avenel, NJ 07001, USA. POSTMASTER: Please send address corrections to *Annals of the ICRP*, c/o Elsevier Science RSO, Customer Support Department, 655 Avenue of the Americas, New York, NY 10010, USA.

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by

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UK | Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK

USA | Elsevier Science Inc., 660 White Plains Road, Tarrytown, New York 10591-5153, USA

JAPAN | Elsevier Science Japan, Tsunashima Building Annex, 3-20-12 Yushima, Bunkyo-ku, Tokyo 113, Japan

First edition 1998
ISBN 008 0043 8598
ISSN 0146-6453

Published quarterly (March, June, September, December)
December 1998 issue

Typeset by Variorum Publishing Ltd, Rugby
Printed and bound in Great Britain by Polestar Wheatons Ltd, Exeter

PERGAMON

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Guest Editorial

A NOSTALGIC TRIBUTE

The recent death of two well known characters in radiation protection, Harold Wyckoff at the age of 89 and Karl Morgan at the age of 92, reminds us that a venerable generation to which we owe much gratitude is fading out. Names which used to fill us with awe and respect, such as Bugnard, Failla, Holthusen, Mayneord, Parker, Sievert, Stone, and Taylor, are no more than names to the youngest generation, if known at all. With the demise of Wyckoff and Morgan and already some years ago of 'Bill' Pochin and Henri Jammet, the generation following the true pioneers is now abated. High-spirited individuals full of life and wits are at best transformed to memories. They are all worth a tribute to their achievements when the Commission now has opened its Annals for editorial comments.

Harold O. Wyckoff, who during his active years was in charge of the radiation physics laboratory at the U.S. National Bureau of Standards, was Secretary of the International Commission on Radiation Units and Measurements, ICRU, during the 1950's and 1960's and chaired the ICRU during the period 1965–1985. He was also a member of ICRP Committee 3 on the protection against x rays. Together with Lauriston Taylor, whom he succeeded as Chairman of ICRU, Harold very actively worked for intensifying the co-operation between the two commissions, ICRP and ICRU.

Karl Ziegler Morgan merits appreciation for his early work for ICRP as Chairman of its Committee II when, in the 1950's and with the help of Walter Snyder and other members of his Oak Ridge group, his committee produced the first comprehensive presentation of maximum permissible concentrations and body burdens for a large number of radionuclides. Morgan was also active in the establishment of the Health Physics Society and the International Radiation Protection Association (IRPA). However, after he left the Commission and became an emeritus member in 1973, Morgan unfortunately developed a strong aversion to ICRP and a penchant for making statements that his former ICRP colleagues found increasingly surprising.

Edward Eric Pochin, known universally as Bill, and Henri Jammet both contributed greatly to the standing of the Commission. Their participation in the meetings can best be described as colourful. Both had short fuses. Bill sublimated his occasional frustrations by publicly breaking a pencil. When he was in the chair, he did this surreptitiously in his pocket. He also made a remark that the Commission does well to remember. Speaking of protection standards, he said, 'if a number is right, twice that number is not wrong'.

Henri Jammet served for many years as the Chairman of the Commission's Committee 4. This was an enthusiastic and ill-disciplined group that sometimes infuriated its Chairman. His English was good, but not good enough to disentangle three simultaneous speakers. He sometimes erupted and threatened to make rapidly spoken French the working language. The Committee's discipline then improved, but not for long.

To sum up, those of us who have worked for long periods with the Commission recognise an enormous contribution from the great names of the past. The Commission is an unusual body, with very little formal constitutional status. It owes much of its influence to the professional and personal contributions from its great names.

JOHN DUNSTER BO LINDELL

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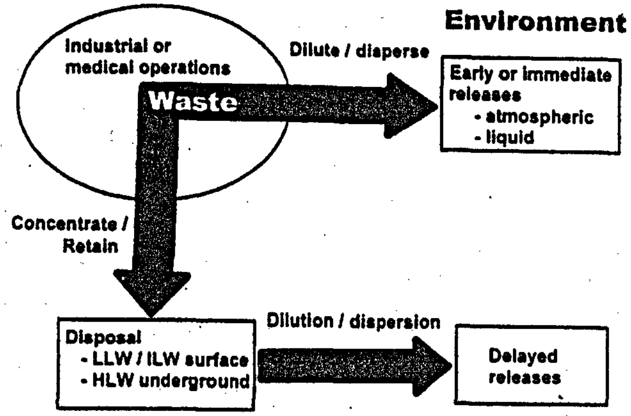

Fig. 1. Waste production system and disposal strategies.

(6) In the case of disposal of long-lived solid radioactive waste using the 'concentrate and retain' strategy, the main protection issue concerns exposure that may or may not occur in the far future, i.e. a situation of potential exposure. Even if the disposal system is well designed and properly managed, there may be releases to the environment. However, an effective waste disposal system will retain the wastes during the period of greatest hazard with only residual radionuclides entering man's environment in the far future. Any corresponding estimates of doses to individuals and populations will have growing associated uncertainties as a function of time due to incomplete knowledge of the future disposal system behaviour, of geologic and biospheric conditions, and of human habits and characteristics. Furthermore, as knowledge of a waste disposal system may eventually be lost, verification that protection is being achieved, in the same manner as for current releases, cannot be assumed. Neither can it be assumed that effective mitigation measures will necessarily be carried out. Nevertheless, the Commission's system of protection can be applied to the disposal of long-lived solid radioactive waste.

(7) The strength and coherence of the Commission's system of protection lies in its ability to cover a wide range of circumstances in a consistent way, although application of the Commission's system in the case of disposal of long-lived solid radioactive waste requires elaboration. The Commission issued recommendations for the disposal of solid radioactive waste in *Publication 46* (ICRP, 1985b). The aim of the present publication is to supplement, update, and clarify those recommendations in the light of more recent developments including the Commission's policy for disposal of all types of radioactive waste as summarised in *Publication 77* (ICRP, 1997b).

(8) This report is structured as follows. Section 2 describes options for solid waste disposal. Section 3 describes the Commission's current recommendations relevant to radioactive waste disposal, and the application of these principles to the disposal of long-lived solid radioactive waste is described in section 4. Section 5 contains the main summary and conclusions.

2. BACKGROUND

2.1. General considerations

(9) Radioactive waste arises from a wide range of activities: the use of radionuclides in hospitals and research laboratories; the use of radioactive materials in industrial processes; the nuclear fuel cycle including production of electricity by nuclear power; and, as a by-product, from processes not directly using the radioactive properties of different materials. These wastes require appropriate management.

(10) There is a close relationship between the different waste management operations which means, inter alia, that the conditions of the disposal should influence the other operations. A variety of different management approaches have been developed in order to accommodate the widely ranging characteristics of radioactive waste. An appropriate radioactive waste classification system allows a general assignment of management approaches to different types of radioactive waste.

(11) The three principal characteristics of waste that influence its management are its physico-chemical properties, particularly the half-lives of the radionuclides, the radionuclide content, and its volume. The waste may vary from slightly radioactive, such as most of the waste generated in medical diagnostic procedures, to highly radioactive, as in vitrified reprocessing waste or spent sources. Wastes can be generated as solids, liquids, or gases, some of which may require conditioning and treatment prior to disposal. Volumes range from, e.g., small sealed radiation sources, to very large volumes, such as wastes arising from decommissioning of nuclear facilities. The largest activities are generated by defence and civil nuclear fuel cycle operations. However, large volumes of waste are generated by some industries using naturally occurring radioactive materials.

(12) Separation and transmutation of long-lived radionuclides into radionuclides with more favourable properties, e.g. shorter half-lives, could theoretically reduce the long-term hazard of the waste. Activity levels in the short-term would, however, increase. The technical and economic feasibility of transmutation has yet to be demonstrated. In any case it would involve a requirement for additional facilities and corresponding occupational exposures, and the need for disposal would presumably remain for residual waste.

(13) Prior to disposal, storage could play a useful role in providing a period during which radioactive decay reduces the hazard potential. Solid wastes containing only short-lived radionuclides may, after a sufficient period of storage, be released into the environment. With heat-generating waste, disposal may be more easily facilitated after some decades of storage because the heat is mainly caused by short-lived radionuclides.

(14) Storage of waste implies surveillance and maintenance of the storage facility. Storage, therefore, may involve operational exposures to personnel, continuing risks of accidental releases, financial provisions to cover operating and decommissioning costs, continuing reliance on institutional control, and thus the imposition of some burdens on future generations. Similar considerations apply if retrievability is added to the disposal concept.

2.2. Technical options

(15) Options for the disposal of solid radioactive waste usually rely on multiple engineered and natural barriers, the combination of which is referred to as disposal system. The overall performance of the disposal system relies on prevention or retardation of radionuclide migration to the environment accessible to man through the combined and/or complementary performance of the various barriers.

(16) The choice between disposal options involves consideration of the waste's radiological hazard, the time-scale over which the waste will be hazardous, the volume of waste, as well as economic and social factors. The following disposal options are currently favoured or have been considered.

- *Ordinary refuse disposal* may be suitable for waste with very low radionuclide contents.
- *Shallow land burial* in trenches, engineered facilities, or via in situ stabilisation may be suitable for large volumes of solid wastes such as the residues from the mining and milling of uranium bearing ores and short-lived low and intermediate level waste from the nuclear fuel cycle. The geologic and engineered barriers can immobilise and retain the radionuclides for a considerable time. The proximity of the waste to the surface may, however, require institutional control, maintenance, and surveillance for extended periods of time to reduce the possibility of inadvertent human intrusion or loss of containment due to natural processes.
- *Disposal in deep geologic formations* has the potential to provide a very long period of isolation from the accessible environment and a greatly reduced possibility of inadvertent human intrusion if proper characteristics are selected for both the natural and the engineered barriers within the disposal system. Salt formations, granite, clay, basalt, and volcanic tuff have all received attention, so far, as potentially suitable geologic formations.
- *Disposal into space or into solar orbit* has not been further pursued because currently the technical and economic feasibility is questionable. Disposal of solid radioactive waste on or into the ocean floor (*sea dumping or sub-seabed disposal*, respectively) was once an option for some wastes under the terms of the London Convention, 1972, and a definition of the material suitable for dumping was provided (IAEA, 1986). Low level wastes were dumped up until 1982 at a site in the North-east Atlantic. However, in spite of extensive scientific studies demonstrating that the site could continue to be used for the dumping of packaged radioactive wastes (NEA, 1985), in 1993 the Consultative Meeting of Contracting Parties to the Convention decided to prohibit the sea dumping of all types of radioactive waste. The prohibition came into effect, on 20 February 1994, by amending the Annexes to the Convention.

(17) For low and medium/intermediate level waste a number of disposal options are available, on the surface, subsurface, and deeper underground. Internationally, disposal in deep geologic formations is currently the proposed strategy for disposal

of solid high-level waste and other long-lived radioactive waste such as waste containing long-lived alpha emitters.

(18) States have adopted obligations for safe management of spent fuel and of radioactive waste (IAEA, 1997).

2.3. Radiological assessment

(19) The radiological assessment of a disposal system for solid radioactive waste needs to consider the various possibilities for human exposure. Processes that could lead to human exposures have to be identified on a site-specific basis. (For simplicity 'processes' should be read in this document as representing features, events, and processes.) Some natural processes may result in a gradual release of radionuclides to the environment. A typical example is the gradual degradation of the waste package due to corrosion and the consequent release of radionuclides. Subsequent natural processes that could lead to human exposure may include transport of radionuclides by groundwater with the associated processes of sorption, diffusion and dispersion. Other, less likely, natural processes may disrupt or otherwise affect the performance of the disposal system, e.g. seismic events and glaciation.

(20) Human actions in the future may also disrupt a waste disposal system. A human action affecting repository integrity and potentially having radiological consequences is known as human intrusion. The consequences for a deliberate intruder are primarily considered the intruder's responsibility. There is also the possibility of inadvertent human intrusion after knowledge of the disposal system has been lost, i.e. actions taken unknowingly by someone that disrupt the waste disposal system. These actions include inadvertent drilling into a deep repository and inadvertent construction on a shallow repository. Such inadvertent actions are the main issue for human intrusion in the long term; in this report, the term human intrusion refers to inadvertent intrusion. In any case, intrusion may also have consequences for other groups.

(21) Site specific assessments are essential in order to evaluate the radiological consequences of waste disposal. They are also necessary to understand, describe, quantify, and optimise the role of the different barriers of the disposal system and its subsystems. Assessments consider a number of scenarios where a scenario is defined as one possible combination of specified processes affecting the disposal system that could lead to radiological consequences. Typically, an assessment consists of the following elements, which are usually dealt with in an iterative manner: system understanding, scenario analysis, development of conceptual and detailed system models, consequence analysis, uncertainty and sensitivity analysis, and interpretation of the calculated results. An integrated assessment will evaluate the expected system evolution as well as less likely system evolutions including those caused by disruptive events of natural origin or as a result of human intrusion.