

ADVISING THE PUBLIC ABOUT RADIATION EMERGENCIES



NCRP COMMENTARY No. 10

ADVISING THE PUBLIC ABOUT RADIATION EMERGENCIES

A Document for Public Comment

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Preface

In 1986 Scientific Committee 63-1 of the National Council on Radiation Protection and Measurements (NCRP) was asked to prepare a document on "Advising the Public about Radiation Emergencies." The result is this Commentary. Suggestions for informing the public about radiation and about emergencies that involve radiation are presented. Included are information sources, perceptions, the need for credibility, a discussion of what information can prove valuable in a radiation emergency, and a proposed radiation index, *i.e.*, a numerical scale for comparison of various radiation exposures.

Important to the question of information available in an emergency is the fact that our knowledge of exposure pathways and biological effects has continued to increase. It is now possible to estimate rather accurately the major radiation effects on both people and their environment from the release of radioactive materials. Had there been greater understanding of these matters by the public, it might have been possible to avoid much of the psychological stress generated by the Three Mile Island emergency. That event signaled an urgent need for prompt, scientifically sound, simply expressed and widely available information. The bedrock foundation of any plan to protect the public from radiation effects, particularly in time of emergency, is reliable information presented to an informed public.

The subtitle of this Commentary, "A Document for Public Comment," reflects the desire of the NCRP to begin a dialogue on what information and what form of presentation can prove helpful to members of the public in assessing emergency situations with potential for radiation exposure. The Council recognizes the inherent difficulty of formulating guidance on means of meeting the public's information needs in connection with radiation and seeks input from those with interest in and concern for the problem. In particular, the Council seeks reaction to the proposed "radiation index" presented here.

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The Council wishes to express its appreciation to the Committee members and advisor for the time and effort devoted to the preparation of this Commentary.

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1. Introduction

Technologies that use or produce radiation or radioactive materials, like many other complex technologies, have the inherent potential to cause emergency situations in which public safety may be jeopardized. Professionals engaged with such technologies are trained to minimize risk and potential harm, even in emergencies, but there can be no question that emergencies are public events and that, as such, the public must be informed. The degree of the public's involvement in an emergency will, of course, depend on the type and scale of the event but the need for information is present in all cases. This Commentary reviews salient features involved in the provision of information to the public relating to radiation emergencies.

Section 2 outlines sources of information available to the public for a broad understanding of technology and science in general, and radiation matters in particular. Section 3 addresses the vital matter of credibility. In Section 4, matters of perception and their influence on the usability of information are assessed. Section 5 directs attention to the role of information sources during the emergency itself. Section 6 presents a survey of the types of information that can prove helpful to the public in connection with a radiation emergency and exhibits a proposed index for helping people comprehend the magnitude of radiation levels and their impacts. Means for improving the dissemination of information and the public's capacity to use it are outlined in Section 7. Finally, appendices provide information about emergency response organizations and additional information about the proposed radiation index.

2. Sources of Information

The informed public that is vital for successfully dealing with a radiation emergency cannot be developed after the emergency has begun. Effective dissemination of reliable information during an emergency is vital; the success of such an effort depends, to a substantial extent, on the public's capacity to use the information provided. This, in turn, depends on the public's familiarity with the issues based on their previous "education." Education is taken here to mean not only the formal training given by schools and comparable institutions and organizations, but also the results of having received and processed information from all sources that assist in evaluating and understanding radiation matters. It is too late to develop an informed public after an emergency has begun, so the process should be an ongoing activity. Since the sources that contribute to this "education" are diverse it is worthwhile to direct some attention to this topic.

2.1 Broadcast Media and Films

Broadcast media and films constitute a major source of information for the public in the United States, particularly for adults who are no longer in school. News stories with technological content provide a background of information that is likely to be drawn upon in connection with subsequent radiation events. "Specials" and documentaries can focus on sophisticated subjects in some depth to provide a more comprehensive collection of information that can subsequently be helpful in evaluating radiation matters. Dramatizations can take advantage of the mystique and wondrous character of technological entities like radiation to entertain. If factual, these too, contribute to the background of understanding brought to the evaluation of subsequent events involving radiation.

2.2 Print Media

2.2.1 *News Stories*

In newspaper and news magazine stories, there are frequent opportunities to include background material with the basic facts. All readers cannot be expected to read or absorb everything presented, but such stories can include important sources of reliable information, concerning radiation and its potential impact on human health.

2.2.2 *Feature Articles*

For a large segment of the public, feature articles in newspapers and magazines provide knowledge about technological matters. These sometimes focus directly on radiation matters

and if they contain reliable information they can contribute importantly to the "education" needed by members of the public for understanding the potential impacts of a radiation emergency.

2.3 Specific Publications

2.3.1 *Popular*

Books and pamphlets about technical matters are widely available to the general public. These come from commercial publishing houses, public interest groups, industry and from government agencies with responsibilities for providing information. These also constitute an important source of information.

2.3.2 *Technical*

Although the literature associated with technology and science is extensive, it is not likely to be used to a marked extent by members of the general public except as a library resource. It does, of course, constitute an information source useful to professionals in various fields. For them the technical literature provides important information of value in connection with radiation emergencies.

2.4 School Curricula

The formal education received in school is a primary source of information that subsequently will be brought to bear in an evaluation of radiation matters. Although specific science training can be important, the overall fund of knowledge developed and the appreciation of the usefulness of analysis *per se* can also be important when an individual is subsequently assessing information on a new or complex subject.

2.4.1 *Elementary and Secondary Schools*

Graduation requirements in some states specify satisfactory completion of a course in general science or two specific science courses. With increasing pressure to emphasize the "basics" in education this may be the only scientific background that many members of the public ever receive. Thus, these science courses may constitute the only strictly "scientific" training available for subsequently addressing technological issues.

2.4.2 *College/University Curricula*

General science courses for nonscience majors, while they rarely include elementary radiation science topics, may constitute an important source of information about scientific matters. For science majors, of course, their specialization exposes them to scientific concepts and approaches even if their particular course of study does not encompass details of radiation matters. Students taking courses in physics, chemistry and nuclear engineering or courses involving radioactive tracer techniques in chemistry, biology, engineering, medicine or agriculture receive some generalized training in radiation matters.

Although there is no *a priori* reason to exclude radiation information in courses that cover environmental, ecological or biomedical topics, there is a general reluctance to introduce special topics such as radiation into these courses. When special courses which include radiation science are offered, these tend to be limited to specific majors.

2.4.3 *Textbooks and Other Materials Used in Schools*

Textbooks constitute an important source of information. Certainly, many students obtain their basic understanding of scientific and technological matters from this source. Radiation science is not universally dealt with in textbooks and teachers may have to rely on their own handouts. The National Science Teachers Association has published a book, *The Content Core, A Guide for Curriculum Design* (NSTA, 1992). This book, written with National Science Foundation support, provides an integrated approach to inclusion of radiation science from grades 6 through 12 for all sciences. In a pilot study in Houston, students, teachers and parents were enthusiastic about this approach (Eisner, 1992).

In 1994, the Health Physics Society (HPS) announced receipt of a grant from the U.S. Department of Energy to hold science teacher (grades 1 to 12) workshops on radiation topics in 1994 to 1995. Participating local HPS chapters and American Nuclear Society sections will hold 8 to 10 h training sessions and provide each teacher with a teaching plan, materials including diskettes for interactive personal computer learning, and make available radiation detection instruments.

2.4.4 *Personal Experience and Word-of-Mouth Exchanges*

Personal experience and word-of-mouth exchanges constitute important sources of information that may have a significant effect on how an individual processes information about a radiation emergency. Someone who has experienced a course of radiation therapy or a complex diagnostic radiation study may have a different view of radiation matters than someone who has never been in a radiology suite. Similarly, an individual who has heard about radiation applications from a friend who is a nuclear engineer or health physicist may have a viewpoint different from other members of the general public.

3. Credibility

Credibility is important for all persons involved with each information source including government officials, journalists and nuclear facility spokespersons. Other factors that determine the receptivity of the public, including their perceptions of radiation risks, are discussed later in this Commentary, but credibility is a key factor. It is easier to lose credibility than to establish it and, once lost, it is difficult to regain.

Journalists are particularly and justifiably unforgiving when it comes to incorrect or misleading information released by public health officials. Health officials have a responsibility to release factual information promptly without attempting to color or soften bad news. There is a delicate balance between withholding information to check facts for accuracy, and withholding information because of potential negative impact. Journalists and the public expect to obtain early information even if it is unconfirmed. Commercial nuclear power plants are required by law to notify federal, state and local government officials within 15 min after declaring an emergency. These officials then must have the capability to notify the public within an additional 15 min (NRC, 1981). The requirements for prompt information can be perceived as compromising the requirement for accuracy, but failure to be both prompt and accurate may lead to loss of credibility.

4. Perceptions

The success of any effort to inform the public about radiation risks depends on sociological, political and financial aspects, and on the perception of the public with respect to the risks of radiation exposure, some of which are discussed below. The expected dramatic increase in the public's desire for information in an emergency may overcome constraints that are known to be strong. These constraints should be factored into emergency planning to take full advantage of every opportunity to provide information.

Radiation exposure is *perceived* by many to carry a very high risk to health compared with risks from other hazards associated with modern technology (Slovic, 1990). This concern about radiation exposure is believed to make it difficult to inform the public adequately before, during and after a radiation emergency.

Research has identified radiation risk perception as particularly complex (Sandman, 1986). Specific elements that are thought to increase the public's fear of radiation include the following:

1. Radiation risks are considered to be new and uncertain.
2. The technologies associated with radiation are complicated.
3. Radiation accidents are perceived to be beyond one's control.
4. Radiation-producing technologies such as generation of electricity by nuclear power plants are considered by many to be both dangerous and nonessential.
5. Serious radiation emergencies and catastrophes have occurred in the past (*e.g.*, the war-time atomic bombings and the accident at Chernobyl).
6. Radiation effects evoke strong emotional feelings because they are associated with nuclear weapons.
7. Radiation effects are perceived to be extended to future generations.
8. Radiation accidents are usually thought to involve airborne contamination, "fallout," and hence to have global consequences.
9. Radiation is not detected by our senses.
10. Radiation can cause a dreaded disease, *e.g.*, cancer.

Historically, fears of technologies such as machine shops, self-powered vehicles, electricity and natural gas have been abated by time and economics. *Familiarity* is an important catalyst to a realistic perception and acceptance of any hazard.

5. Sources of Information Available During a Radiation Emergency

Many of the sources of information cited earlier as contributors to the background knowledge and understanding by the public will also serve as principal sources of information during a radiation emergency. It is worthwhile to survey these here.

5.1 Broadcast Media

The ubiquity of the broadcast medium makes it a crucial channel of information during an emergency. Broadcast news is brief, graphic and highly competitive. Unless a news story is sustained there is little room for background or perspective at the time of an emergency. Since senior editors must choose what to include and how to phrase what is broadcast, efforts should be made to acquaint them with both available information and qualified experts.

5.2 Print Media

As cited earlier in connection with general information, stories that appear in newspapers and news magazines can include coverage in greater depth than is frequently possible in broadcast media coverage. This attribute is normally amplified during a radiation emergency by the public's strong desire for information. The print media can thus serve as a source of detailed information to which the public can turn immediately and also as a repository that can be re-examined during the course of the emergency.

5.3 Official Sources

Official information is separately identified here in the belief that, during an emergency, this information source achieves a degree of authority and credibility that overrides the characteristics of other public information channels.¹

The 1992 Federal Response Plan was prepared through the efforts of many agencies and forms the basis for federal assistance to each state and its local governments impacted by a catastrophic or significant disaster or emergency (FEMA, 1992). This plan covers all emergencies, including radiation emergencies, with pages devoted to public information. Additional recommendations have been made by the National Academy of Public Administration (NAPA, 1993) on "building an emergency management system to meet people's

¹Information about emergency response organizations is set out in Appendix A.

needs in natural and man-made disasters." That report, *Coping with Catastrophe*, was mandated by the U.S. Congress and was prepared for Congress and the Federal Emergency Management Agency (FEMA).

5.4 Those Involved in Providing Information to the Public

5.4.1 Media

Journalists assigned to a story are not likely to be specialists on radiation emergencies except for the most serious radiation emergencies and for the largest media organizations (Sandman, 1986). It is important to consider how journalists compose stories. Much of the material found in any one story or article is usually drawn from official releases, eyewitness accounts, standard data bases, recently released reports of scientific or governmental organizations, or from previous news reports. New information, points of view or opinions are usually drawn from personal contacts or sources. A good reporter has credible, well placed sources, access to standard or routine information, usually *via* computer, and the ability to put the facts quickly into a simple, personalized and, most importantly, an attention-getting and interesting story.

The initial priorities for a journalist covering an emergency are credible sources of information, a rapid relay of information and a clear estimate of any danger. Questions on the details of risk assessment, how certain the experts are in their assessment, and the reason protective actions are necessary may be the subject of later stories or may be ignored entirely. Actual or projected risk or danger is not ignored, of course, since this is the reason there is a story in the first place. Most stories either establish the "danger" in the opening line of their story or take the "danger" to be understood. The potential risk or hazard usually comprises a very small part of the story. If it is necessary to be quantitative about the risk in a story, a reporter is likely to ask, "How does the danger compare to the government's standard of safety?" Any standard established by the government concerning radiation is frequently interpreted as the demarcation between "safe" and "unsafe."

Journalists tend to interpret the word "objectivity" in a different manner than do scientists. An "objective" report to a journalist is one that equitably presents all sides of an issue. The implication is that all stories have two or more points of view that should be presented. Distortion can result when information is slow to be released, is given out in a variety of contexts that were neither planned nor well thought out, or when the information given out is conflicting.

In addition to obtaining information on the emergency, reporters have the task of trying first to understand the information and then to communicate the information to the public. There are several additional motivations at this point that are very important. They need to simplify, dichotomize and personalize the information at hand (Sandman, 1986). If the source of the information is unable or unwilling to simplify and personalize a story then the reporter is forced to do so. It has been suggested that this is one of the reasons stories about radiation and emergencies often contain inadvertent distortions and inaccuracies (Sandman and Paden, 1979).

5.4.2 *Emergency Response Personnel*

The public will accept advice and guidance from emergency personnel if it is confident that the personnel are credible and capable of comprehending and dealing with the emergency. Emergency workers should have a satisfactory understanding of radiation hazards and means to deal with them. Since the backgrounds of these workers cover a wide range of experience, training must be individualized by categories. A number of documents useful to emergency personnel are available, *e.g.*, AEC (1969a), FEMA (1985a), IAEA (1986), NCRP (1981), NRPB (1986) and Saenger (1983).

6. What Information Can Prove Valuable to the Public in Connection with a Radiation Emergency?

6.1 General Needs

The basic premise of this Commentary is that people need to have an elementary understanding of radiation fundamentals, information on the types of accidents that can occur and be cognizant of the feasible responses to emergencies. Some of this information should be made available before an emergency arises and the rest obtainable during and after the emergency. The General Accounting Office (GAO, 1987) found that "no federal agency assesses public knowledge of radiological emergency procedures." However, FEMA does have the responsibility for providing information to the public and for training and providing assistance to state and local radiation response personnel (FEMA, 1985b).

6.2 Radiation Fundamentals

Members of the public need to know about radiation and radionuclides in terms that are comparable to those used in connection with other hazards in the environment. It is desirable for the public to know the meanings of the terms and units with which radiation and its effects are described. It is remarkable how readily specialized terms and information become common public knowledge after a major accident. The goal should be to accomplish much of this familiarization before an emergency has occurred.

Texts should be available to convey basic facts, *i.e.*, potential hazards and options for radiation protection. Other recommended topics include the following:

- description of radiation types
- radiation sources
- interactions of radiation with matter
- radionuclide generation
- radioactive decay
- environmental movement of radioactive materials
- modes of exposure (external, inhalation, ingestion)
- behavior of radiation radioactive materials within the body
- levels of measurable effects on humans and the environment
- limitation of exposure by time, distance and shielding

A number of textbooks are available on these topics. Also available are a few books directed to a general audience, reports used by agencies and training manuals.² Emergency response agencies have prepared manuals to guide their staffs and other officials, including police and fire fighters who deal directly with the public. Descriptive material also is available from national and state agencies.³

6.3 A Radiation Index

The public's understanding of radiation matters might be enhanced if an index were available to facilitate comparison of radiation exposures from various sources. An example of such an index is shown in Figure 6.1. This index provides a linear scale that can be used to compare the magnitude of a given radiation exposure with any specified benchmark exposure. The benchmarks chosen are the radiation exposures associated with a variety of circumstances, some of which will be familiar to many people.

The numbers shown on the radiation index represent the effective dose associated with the radiation exposure. Technical readers would want to know that these numbers give the effective dose equivalent in hundredths of a millisievert (mSv), chosen so that decimal fractions are not needed on the index. This will also allow them to develop alternate benchmarks and ensure that the index value given is appropriate in a particular case. In using the index, the units need not be specified because valid comparisons can be made using index values without having to know or understand radiation exposure quantities or units.

It needs to be recognized that index values must be given in the same context that values of effective dose equivalent are given. That is, it must be clear that a given index value refers to a particular exposure to a particular individual(s) over a specific time. For example, it might be used for describing the exposure of a patient during a diagnostic study or the average population exposure from a release at a particular site. The latter exposure should be characterized as the index value for exposure over a specific time period, *i.e.*, 1 d, 50 y or lifetime. Although the index could also be used in the context of a collective exposure, it would be important to develop a collective benchmark for comparison.

The use of a common descriptor for radiation exposures during an emergency can provide members of the public with the information needed to form an independent judgment of the situation. Journalists can use the index to explain radiation exposures in a familiar context. Detailed information about the index is set out in Appendix B.

²AECL (1981), AMA (1981), DOE (1986), Hall (1976), Hüber and Fry (1980), IAEA (1979), Mettler and Upton (1994), NCRP (1987a), NRPB (1986), UNEP (1985) and Upton (1986).

³The Department of Defense, the Food and Drug Administration, Environmental Protection Agency, and also from operators of nuclear power plants and from government support agencies such as the International Atomic Energy Agency. See also DNR (1980), DOT (1980), FEMA (1983a; 1983b; 1984a; 1984b; 1985a; 1987; 1992), GPC (1988) and IAEA (1969; 1977).

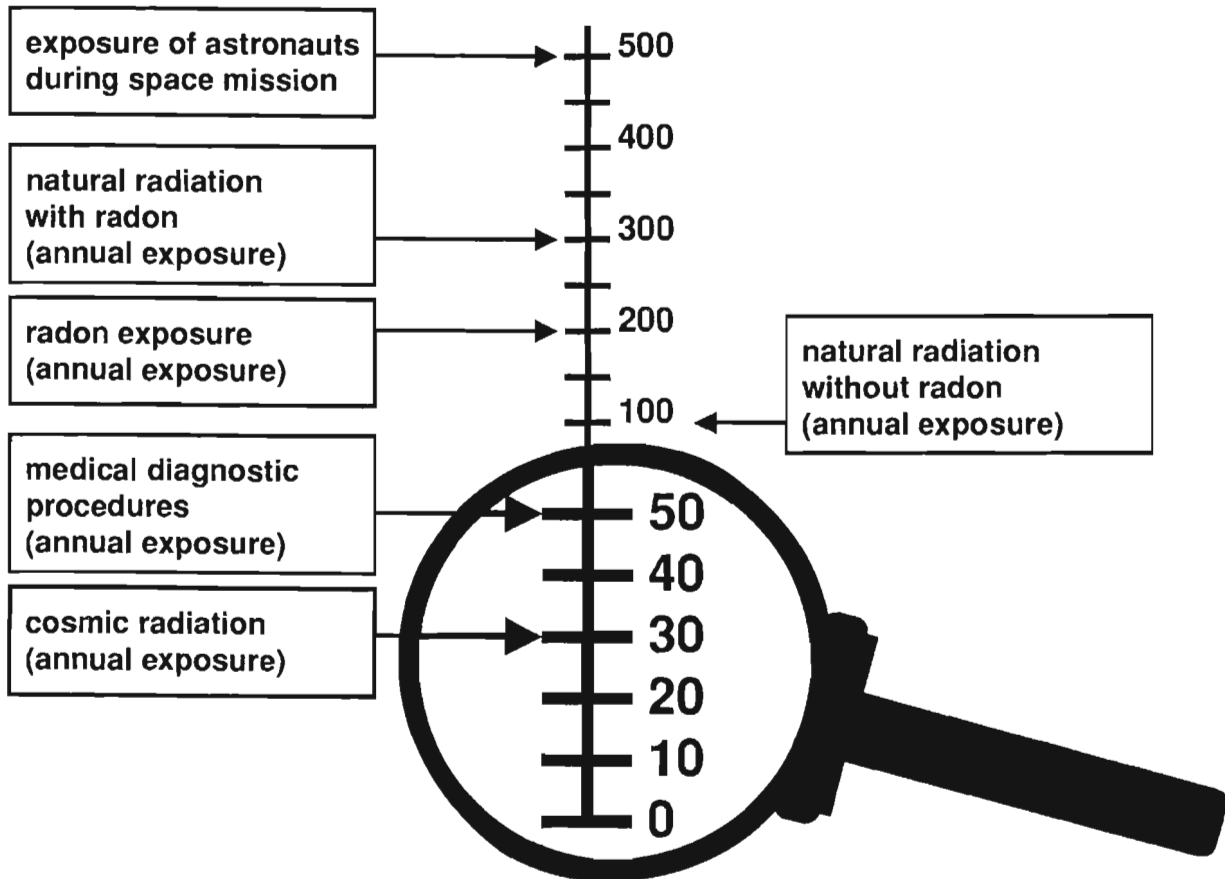


Fig. 6.1. The radiation index . The numbers shown represent the effective dose equivalent associated with the radiation exposure in units of hundredths of a millisievert but the units need not be employed when specifying an index value.

6.4 Information Relating to the Specific Emergency

When a radiation emergency occurs, the public needs information specific to that situation, such as the scope, magnitude and potential duration of the emergency. Specific guidance on actions to be taken or avoided is required. Information about potential radiation exposures that might be encountered must be provided as well as information about potential effects of such exposures. The need for remaining in place, evacuating or taking shelter have to be explained. Information about the safety of available water and food will be needed.

Since appropriate responses to these needs are usually specific to a particular incident, location and time, they need to be organized by a designated response manager. Local citizens need to know who that official is, why they should trust the official rather than other competing voices, and how the action recommended by the response manager fits with the range of possible responses.

The public should have access to frequently updated material about the situation, the identity of responsible officials, the range of possible problems and details of how to respond. Guidance is available from emergency management agencies such as FEMA and its equivalent agencies in the state and local governments concerning nuclear war, facility accidents and transportation accidents.⁴

⁴State and local agencies that at one time or another have provided a variety of notes and pamphlets include: AEC (1969b), DOT (1979), EPA (1990), FEMA (1983a; 1984a; 1990), GEMA (1985) and IAEA (1966; 1985).

7. Improving the Dissemination of Information on Radiation Emergencies and the Public's Capacity to Utilize Information Provided

There are a number of steps aimed at improving the dissemination of information on radiation emergencies and the public's capacity to use such information that warrant examination. These are essentially actions that can be taken now to move toward the desired goal of an informed public.

7.1 Improving Dissemination

Those responsible for the dissemination of information, including both governmental bodies and private organizations, should emulate the newsrooms of major media outlets in having at hand "ready-to-go" information capsules and expertise in preparing concise statements. Also, routes for press releases should be well established prior to any emergency (Thomas, 1981).

The needs of the public and the mass media at the time an emergency is developing are dramatically different from pre- or post-emergency times (Sandman and Paden, 1979). The combination of an increased public demand for information and the great dispatch required of the media during a fast breaking story present a unique opportunity for those who want to provide accurate information on radiation emergencies to the public. Concise packages of radiation-related information should be developed ahead of time for use by the media when a radiation accident occurs.

A considerable body of information relevant to emergency operations has been developed by government agencies, operators of nuclear power plants, international organizations and others.⁵ An effort focused on identification of all existing emergency-related public information "packages" and evaluation of the suitability and coverage would be valuable as a means to identify overlooked topics requiring preparation of additional material. In this connection, special attention should be given to the publications prepared by the Chemical Manufacturers Association for hazardous chemicals. The structure of the procedures developed is directly applicable to radiation emergencies because the approach is to develop community awareness (CMA, 1985). A review of the materials available on radiation emergencies is likely to make evident the scarcity of good video and film presentations on this subject.

A more challenging task would be the development of a comprehensive information program capable of reaching a very large audience. The development of a program that would hold audience interest while presenting important basic information requires the combined talents of specialists in radiation protection, emergency planning, education and

⁵(AEC, 1969b; DNR, 1980; DOT, 1979; 1980; EPA, 1990; FEMA, 1983a; 1983b; 1984a; 1984b; 1985a; 1987; 1990; 1992; GEMA, 1985; GPC, 1988; IAEA, 1966; 1969; 1977; 1985)

entertainment. An innovative approach to meeting this challenge was developed in Russia. A computer geographic information system (GIS) in combination with geographic field verification of data using the Global Positioning System (GPS) has been developed to depict the effects of the Chernobyl accident.⁶ The GIS/GPS combined system can be linked to mathematical models such as a dose forecast model to predict the dose from radioactive isotopes received by people in the affected areas. The information can be readily shared with a wide audience and, if presented in simple terms such as the radiation index, be easily presented and understood.

A number of simpler, more straightforward actions could also contribute to improvement in the dissemination of information relevant to radiation emergencies. One of these involves speaker training for those who must transmit information during an emergency. A lesson learned from the Three Mile Island accident was the value of credible, accessible and responsible sources of official information. Designated individuals need to be trained specifically on how to deliver information and advice to the public *via* the mass media. Any organization that has a primary role in response to a radiation emergency such as a lead state or federal agency, hospitals, police and fire departments and utilities should identify and train spokespersons for their organization. This training should emphasize the requirements of the mass media and identify the best context for delivering this information. All commercial nuclear power plants are required to offer radiological emergency preparedness training to members of the media. Prepared materials similar to those constructed for this purpose could help ensure a consistent delivery of needed information in an appropriate context.

Finally, a review and updating of information currently in data bases to ensure accuracy and currency is needed. Many commercial computerized data bases are used by journalists to compose articles on radiation including: CompuServe, Dialog, Source, Prodigy, Genie, Delphi, BRS/After Dark, Dow Jones News/Retrieval, and Mead Data General's LEXIS and NEXIS (Dvorak and Anis, 1990). In addition, every major newspaper has its own articles on computer for immediate retrieval. The facts contained in these data bases have the potential for widespread and repeated distribution. This emphasizes the need to ensure the accuracy and currency of these sources of information.

7.2 Enhancing the Public's Capacity to Use Information

Some steps that might be taken to enhance the public's capacity to use information relate to education and are of a relatively long-term nature. This does not minimize their importance because it is anticipated that the potential for radiation emergencies will continue.

One of the important elements in the capacity of members of the public to use information about radiation emergencies is the science education that takes place in school. Here teachers play a vital role. Efforts aimed at ensuring that science teachers possess a broad knowledge of radiation science could have an important impact. Workshops on radiation and radiation emergencies might be considered in this regard. Also, text material suited to the level being taught, must be available.

⁶Private communication P. Slovic, Decision Research, January 3, 1994.

While work on teacher development might have the most immediate impact, curriculum development is also important. The public's capacity to use information about radiation emergencies would be improved if materials on radiation, placed in context with other technical and environmental hazards, were incorporated widely in school curricula. Such material could also be used for school seminars and assemblies.

APPENDIX A

Emergency Response Organizations

Radiation emergency response at the state level is usually a cooperative endeavor. The State Emergency Management Agency (*e.g.*, GEMA in Georgia, PEMA in Pennsylvania) manages the response; the state or local police (and possibly fire department) control the site; and the state radiation protection agency provides professionals with radiological competence. Support is provided by appropriate staff from the facility where the emergency occurs or from the shipper and carrier in a transportation accident. Support can also be obtained from the Cognizant Federal Agency; the agency that owns, authorizes, regulates or is responsible for the facility; from local emergency response and radiation protection agencies in larger cities or counties; and from nearby states through regional cooperative arrangements.

For radiation emergencies that are large in scale or associated with federal activities, the Federal Emergency Response Plan (FEMA, 1985b; 1992) provides a support system, including emergency response teams. The teams include trained professionals from laboratories, installations and offices of the U.S. Nuclear Regulatory Commission (NRC), Environmental Protection Agency (EPA), Department of Defense, and the Department of Energy and its contractors. The formal emergency response plan places program development and coordinating responsibility with FEMA.

Members of the public should address questions concerning emergency response to the state emergency management agency. Radiation concerns are best addressed to the state public health agency. Emergency response is activated most directly through the local law enforcement system.

APPENDIX B

Radiation Index

B.1 The Purpose of the Radiation Index

The radiation index is a tool for use by the public to help individuals comprehend the magnitude of radiation levels even if they understand little about radiation and its effects. The index is a numerical scale that can be used to compare the magnitude of real or projected radiation exposures with other routine or documented radiation exposures without resorting to the specialized quantities and units normally used to describe such exposures. Widespread use of the index before an emergency to explain, for example, medical x-ray or radon exposures could make the index familiar and useful to the public during an emergency.

The design of any radiation index requires consideration of:

- biological effects or risks upon which the index is based
- type of scale
- procedure for placing a radiation exposure on the index
- benchmarks
- display of the index
- implementation of the index

Each of these factors is discussed below.

B.2 Index Scale and Biological Basis

The basis for the radiation index shown in Figure 6.1 and the potential benchmarks set out in Table B.1 is the effective dose recommended by the ICRP (1980; 1991), the NCRP (1993) and the EPA (1987) with index values expressed in hundredths of a millisievert. This dose quantity is based on the weighted sum of the absorbed dose to individual organs and tissues at risk of cancer or other biological effects from radiation exposure. The dose to each organ or tissue is assigned a weighting factor which reflects its relative risk of effects, primarily cancer and genetic effects, so that the weighted dose to all tissues can be added to estimate overall risk. For this reason, the radiation index gives a fair perspective on exposures that are below any thresholds for deterministic injury.⁷ The index does not give a fair perspective on large acute exposures that could cause acute biological effects soon after exposure. These effects, however, have been addressed in connection with the assessment of the potential effects of a nuclear attack. See for example NCRP Report No. 42 (NCRP, 1974).

⁷An effect of irradiation for which the severity in affected individuals varies with the dose, and for which a threshold usually exists.

A logarithmic scale or other nonlinear scale could have been used for the radiation index. A logarithmic scale has the advantage of showing more detail at the low end of the index, where most of the routine benchmark exposures occur. The disadvantage to a logarithmic scale is that most people do not understand a logarithmic presentation and, to them, the increase in exposure implied by length on the scale might seem distorted. This same problem exists with the open ended Richter scale index that uses a logarithmic scale for communicating the magnitude of earthquakes.

TABLE B.1 — *Potential benchmarks for the radiation index.*

| Benchmarks | Index Value |
|---|-------------|
| Low-Level Benchmarks | |
| 1. Natural radiation (1 y average) | |
| • radon exposure | 200 |
| • radiation from other internally deposited radionuclides | 40 |
| • cosmic radiation | 30 |
| • terrestrial radiation | 30 |
| • total without radon | 100 |
| • total with radon | 300 |
| 2. Consumer products (1 y average) | 10 |
| 3. Medical diagnostic procedures | |
| • chest x-ray examination | 8 |
| • total (1 y average) | 50 |
| 4. Astronauts (1 space mission) | 500 |
| 5. Three-Mile Island (off-site exposure of the public) | <1 |
| Intermediate-Level Benchmarks | |
| 1. NRC limit for radiation workers (in 1 y) | 5,000 |
| 2. Natural radiation (70 y average lifetime) | |
| • radon component | 14,000 |
| • total | 21,000 |
| 3. Atomic-bomb survivors (average 0.22 Gy) | 22,000 |
| 4. Limit for emergency lifesaving (0.75 Gy, once) | 75,000 |

B.3 Techniques for Determining Index Values

The method for assigning an index number to a particular exposure must be consistent. Disagreements between public health officials over the proper placement of an exposure on the index could undermine public acceptance of the index. This problem is shared by other indices in common use, such as the Pollutant Standards Index (air quality index), the Richter scale, the Consumer Price Index, the Dow Jones Average and many others. The solution to this problem is to have one organization or federal agency calculate the index values.

The radiation exposure under consideration for display on the index need not be an actual exposure already received by a person or population. It would be appropriate during a radiation emergency to estimate a projected exposure the public might be expected to receive at a prescribed location *if* the emergency were to follow a particular sequence of events. A well designed index could be used to initiate appropriate protective actions by the public during an emergency. The EPA and the Food and Drug Administration have established Protective Action Guides (PAGs) that are used by public health officials to decide when certain protective actions need to be taken during radiation emergencies (EPA, 1990; FDA, 1982). A PAG is a projected dose or a range of doses that indicates the need for a particular protective action such as shelter, evacuation, restriction of certain food products, etc. If the projected exposure of the public or emergency workers exceeds a particular PAG, then that action is necessary. Each PAG and the protective action it indicates could be given an index value. During an emergency, public health officials could express projected exposures as index values and the need for protective action would be seen.

B.4 Benchmark Exposures for the Radiation Index

Potential benchmark values for a radiation index are listed in Table B.1. Most exposures are given index values by expressing the effective dose in appropriate units rounded to simple integer values. The units chosen for the example index are hundredths of a millisievert. For example, the average annual exposure of the United States population to cosmic radiation of 0.27 mSv converts to 27 units (0.01 mSv per unit) which is then rounded to an index value of 30.

The benchmarks shown in Figure 6.1 and the additional benchmarks listed in Table B.1 have been identified as examples that would give the public a varied and interesting perspective. Background radiation exposures, for example, are likely to be considered "normal." Other benchmark exposures, such as the exposure received by astronauts in space, are unusual and thought provoking. Some individuals might consider the additional exposure of astronauts to be a "calculated risk" that was considered acceptable for the planned mission. Through these examples, valuable perspective could be gained by the public without having to learn more about the exposures. The following information is an explanation of the individual benchmarks used in this Commentary.

B.4.1 *Natural Radiation and Consumer Product Radiation*

The benchmarks for natural radiation include the doses from external and internal sources of radiation derived from the BEIR V Report (NAS/NRC, 1990), NCRP Report 78 (NCRP, 1984) and NCRP Report 94 (NCRP, 1987b). In the BEIR V Report, the annual effective dose equivalent to the population of the United States and Canada from cosmic rays, terrestrial radiation and internally deposited radionuclides (radionuclides deposited in the respiratory tract, such as radon daughters, are considered separately) are estimated to be 0.27, 0.28, and 0.39 mSv, respectively. These values are assigned index values of 30, 30, and 40, respectively. The BEIR V Report gives an estimate of the effective dose equivalent from radon equal to 2 mSv per y. An average index value of 200 has been assigned to exposure to radon for a 1 y exposure and a rounded value of 14,000 has been assigned to lifetime exposure to radon based on an assumed 70 y life span. The total annual exposure to natural radiation, including radon exposure, therefore has an index value of 300, without radon, the index value is 100. The lifetime exposure to natural radiation is assigned the value of 21,000 based on an assumed life span of 70 y.

The average annual exposure of the population of the United States to the radiation from consumer products is given in NCRP Report No. 95, *Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources*, as 0.06 to 0.13 mSv (NCRP, 1987c). A median value in this range was chosen to produce an index value of 10.

B.4.2 *Medical Diagnostic Exposures*

The largest exposure to the population of the United States from man-made sources of radiation is from medical diagnostic x rays and nuclear medicine procedures. The average annual exposure to these sources has been estimated in the BEIR V Report to be 0.39 mSv for diagnostic x rays and 0.14 mSv for nuclear medicine procedures. The total of 0.53 mSv corresponds to an index value of 50.

B.4.3 *Other Benchmark Exposures*

Dose equivalents to astronauts in the range of 0.5 to 5.0 mSv have been measured during recent United States space missions (UNSCEAR, 1988). Dose equivalents as high as 55 mSv have been measured for prolonged orbital flights by the former Soviet astronauts (the 175 d Salut-6 expedition). A value of 5 mSv has been chosen to represent the exposure associated with conventional space missions giving a corresponding index value of 500.

The annual limit for the exposure of radiation workers established by the NRC is 50 mSv (NRC, 1990). This value corresponds to an index value of 5,000 for a 1 y exposure at the 50 mSv per y limit.

The EPA suggests a once-in-a-lifetime lifesaving action level of 750 mSv for emergency workers (EPA, 1990). It is recommended by the EPA that emergency worker exposures be kept well below this level of exposure. Although this should not be considered a rigid limit under emergency conditions, it does indicate a level of risk that one would not plan to exceed even for lifesaving purposes. This exposure corresponds to an index value of 75,000.

B.5 Index Display

The graphic display of the index and the wording used to denominate the benchmark exposures are important considerations for the index design. The choice of a linear scale does not allow the full index to be displayed without rendering the benchmarks unreadable. A magnification approach, where the low end of the index is displayed as if it were being viewed through a magnifying glass, has been chosen to show the important detail at the low end of the index without losing higher, important benchmarks. The possibility of creating several versions of the index by creating overlays containing different sets of benchmarks needs to be considered. This would allow different exposures to be compared in more appropriate contexts than would a single index display. Also, an expanded index including risks other than those due to radiation might be beneficial for comparisons by the public.

B.6 Implementation

Public interest and awareness are best served in an emergency when exposures are explained in a consistent and familiar context. The radiation index could be a valuable tool for this purpose if it is properly implemented. This would likely require sanction by credible organizations, such as the Department of Health and Human Services and the EPA, for example. It would also require some common channels of use to make it familiar to the public before a radiation emergency occurs. These channels use the radiation index to explain nonemergency radiation exposures such as radon exposure, medical diagnostic exposure, or natural background exposure. The index could also be used to explain the exposure (or nonexposure) of the public during the more frequent minor accidents or incidents at radiation facilities. The index could help public health officials, journalists, industry representatives and others involved in a radiation emergency to speak the same language and communicate to the public the information needed in an emergency.

Any radiation exposure communication message or device needs to be tested to ensure that it is comprehensible and useful as intended. The radiation index is no exception. Research that evaluates the usefulness of the index should be given high priority.

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